MACHINE SHOP PRACTICE

HARRY A. JONES

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f 156
p. 6

f. 22
Foret pour tarauder :- (Diamètre du taraud -
la double profondeur du filet
+ le dégagement

Degagement = 1/4 de la double profondeur
pour acier
1/8 de double profondeur du filet
pour fonte

PROGRESSIVE LESSONS IN

MACHINE SHOP PRACTICE

BY

HARRY A. JONES

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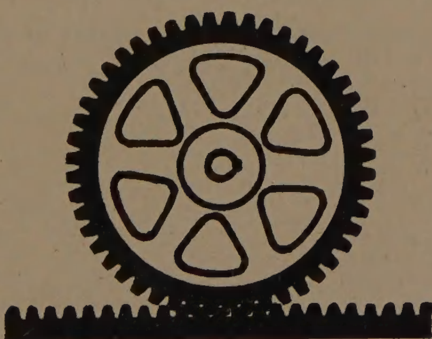
AUTHORIZED BY THE DEPARTMENT OF EDUCATION OF BRITISH COLUMBIA FOR USE IN THE TECHNICAL SCHOOLS OF THE PROVINCE.



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PREFACE

This book is written to assist beginners in laying an intelligent foundation for the study and practice of machine shop work. The course has been carefully thought out after many years of practical experience with boys and men, and is planned to help beginners whether young or old.

The work is arranged on a unit plan, and each lesson has a definite objective which when attained will ease the way for the next step. The same subject matter is sometimes treated several times, but each time in a more advanced manner according to the increased understanding of the student. Difficult problems are only difficult because the student does not approach the problem in easy stages, and it is the object of this book to provide those stages.

The lessons are presented in the form of diagrams on the right hand page and the explanation on the left hand page, so that there is always a close connection between the two. The objectives of the lessons are concrete, that is, some specific job or tool is dealt with in a practical way, at first in a simple manner and later in a more difficult form. At the conclusion of each section is a list of questions which should be used to test whether the work has been properly understood. Time is well spent in making such a check. Sometimes apparent things are quickly forgotten, and in practical work the need for a quick and accurate solution is imperative.

The work presented here has been proved at first hand from practical experience, and nothing has been taken for granted. A Glossary is provided at the end of the book explaining simply the meaning of the technical terms used.

Practical problems are important, as financial loss occurs when mistakes are made; but sound intelligence and common sense sometimes prevent mistakes when the application of formulas and rules not properly understood have failed. This course of lessons, if faithfully carried out by the student, will develop intelligence and common sense. If a solution to a problem appeals to one's reason as being right, it usually is right.

If practical application is made of these lessons, the author is confident that the student will benefit thereby and become a useful and intelligent worker.

HARRY A. JONES.

Vancouver, October, 1926.

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BENCHWORK

LAYING OUT.

Laying out is a process of putting lines on metal, first temporary and then permanent to give guidance to the shaping or removal of metal.

It is obvious that if the lines laid out are incorrect then the work produced will be incorrect, which will mean loss of time and material.

It is well then to lay out work carefully, checking often from the measurements and instructions as given on the working drawings.

Marking the metal. Some metals may be bright and some covered with a black scale called "Iron oxide". Some may be smooth and some rough, so that it is necessary before marking to cover metal with a suitable substance in order that the scribed lines may be seen.

For bright metals use a solution of Copper Sulphate.

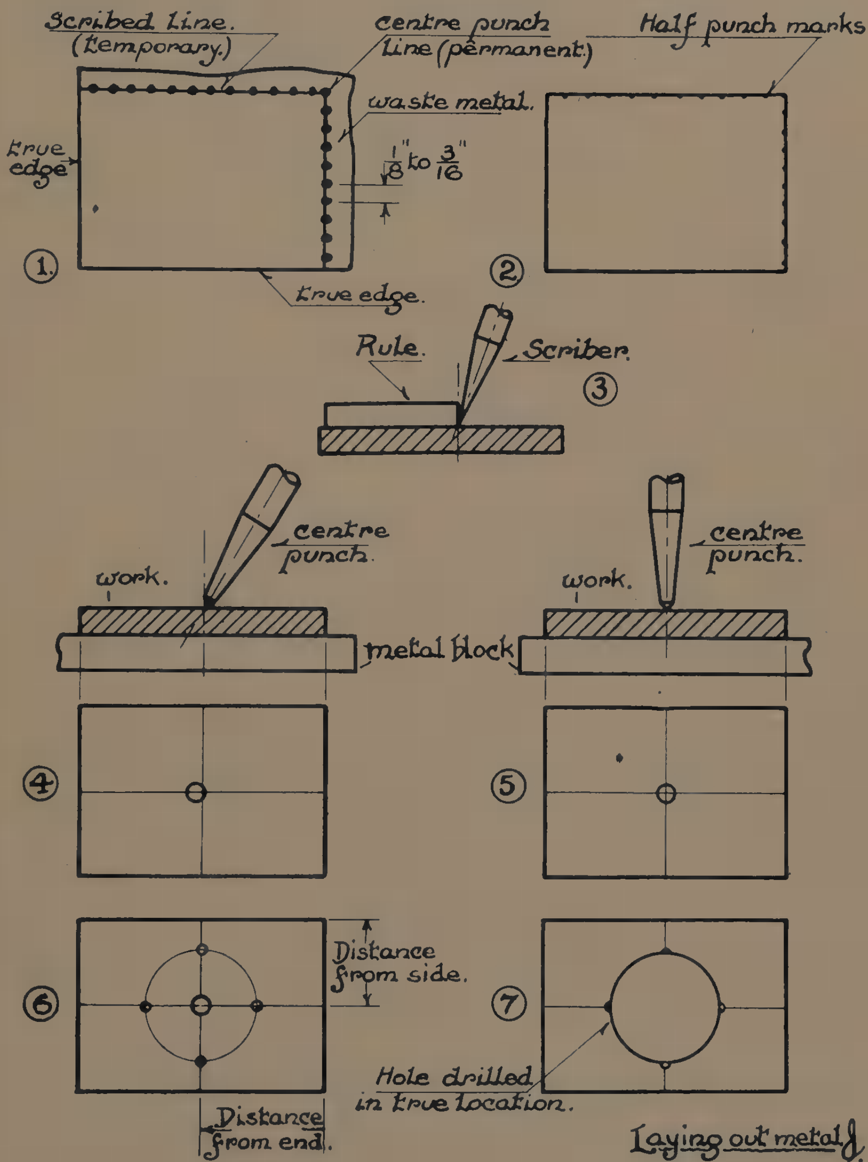
For dull surfaces use ordinary chalk or a solution of whiting put on with a brush and dried over a stove.

Diagram (1) shows a piece of metal laid out after two adjacent edges have been squared or made at right angles to each other. The *scribed line* is a *temporary line* and would be rubbed off unless it were made *permanent* by a series of indentations made by the point of a centre punch. Diagram (2) shows the work after the material has been cut to the line, showing one-half of the original centre dots. If the work has to be finely finished the marks are kept touching the waste side of the line, so that they would just be removed when the work is cut to size.

Use of scriber. The scriber, having a very fine point, will produce fine lines. The point should therefore be held close up to the rule, as shown in diagram (3). If held in a different manner, too much freedom would be allowed the point, and a straight line might not be produced.

Use of centre punch. The point of the centre punch should be placed accurately on the mark, and *held vertical,* as in diagram (5), when struck by the hammer. If it is not vertical, the result will be that the conical indentation will be made off the mark, as shown in diagram (4).

To lay out a hole for drilling. It is necessary when locating a hole to be drilled to take two measurements as shown in diagram (6) and mark 4 points on the circle, so that when the hole is drilled it can be seen whether it was drilled in its true location as shown in diagram (7). If this were not done and the scribed lines were rubbed off there would be no check as to whether the true location of the hole had been obtained.



Laying out metal J.

MEASURING FROM THE RULE.

The steel rule or "scale" is the most common and most used tool of any in the machine shop and it should be the aim of every beginner to obtain a good 6″ steel rule graduated in 8th, 16th, 32nd and 64ths. The rule is a precision tool and should be well taken care of as measurements are never any more accurate than the rule from which they are taken.

Kinds of rules. Rules are made "spring tempered", "flexible" and of various lengths and widths. A rule that is graduated on the end is sometimes very convenient for measuring small dimensions in narrow places. The graduation lines are made of different lengths, 64th's being the shortest and the 1″ lines the longest to save time in reading the measurements.

Reading a "scale" measurement.
First—read number of inches.
Second—number of halves, quarters or eighths.
Third—number of 32nds or 64ths.

Simple method of reading odd sizes:
Examples:

$(2\frac{9}{16}=2\frac{1}{2}+\frac{1}{16})$ $(1\frac{33}{64}''=1\frac{1}{2}''+\frac{1}{64}'')$
$(2\frac{15}{32}''=2\frac{1}{2}''-\frac{1}{32}'')$ $(1\frac{15}{64}''=1\frac{1}{4}''-\frac{1}{64}'')$

It is common to hear such expressions as "one sixty-fourth under one half inch" or $\frac{1}{32}''$ over $\frac{3}{4}''$.

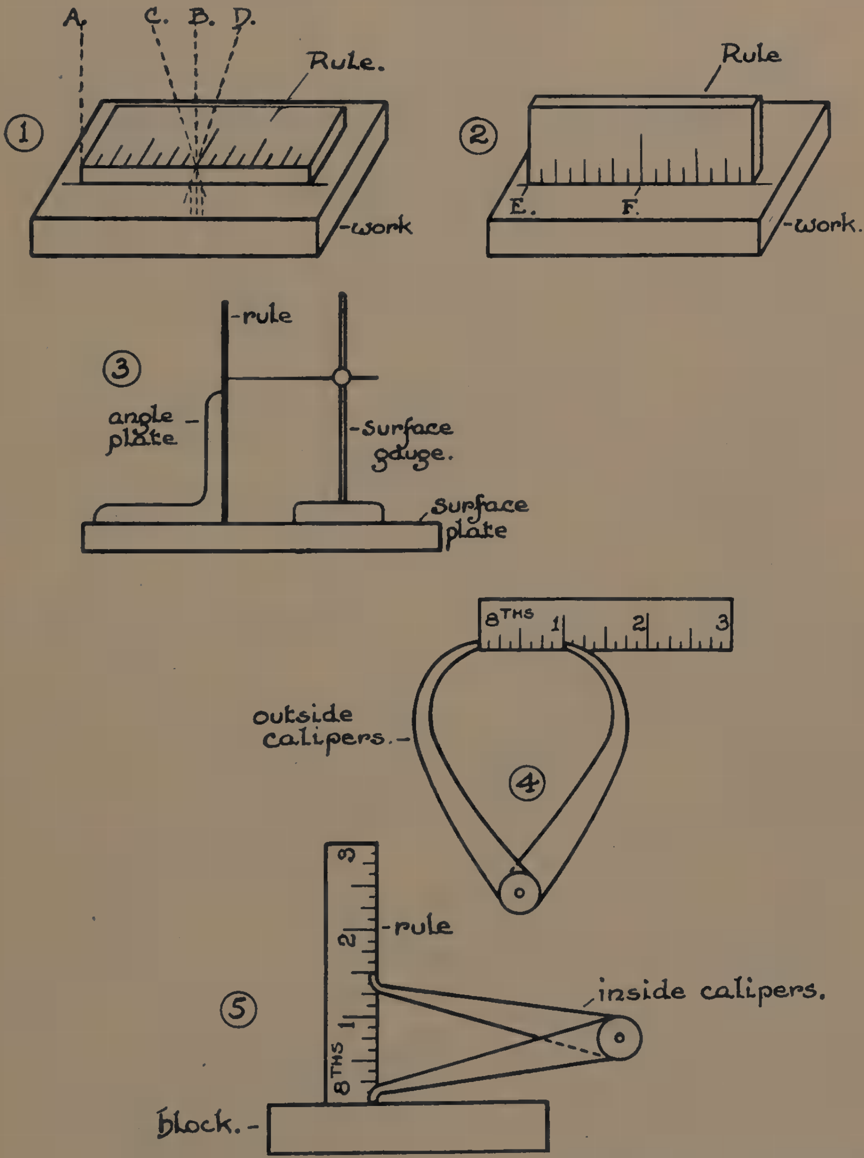
Never speak of four sixteenths, ($\frac{4}{16}$) but always reduce the fraction to its lowest terms such as $\frac{1}{4}$.

Taking measurements from a rule. If measurements are taken from a rule that is thick errors are likely to occur if used incorrectly as in diagram (1). If the eye of the person using the rule is at right angles to the rule as at "A" and "B" when marking the work correct results will be obtained, but if the eye were at "C" or "D" an error would result as illustrated in diagram (1). It is best therefore to place the rule on its edge and mark the work directly from the graduations on to the work as shown at "E" and "F" in diagram (2).

Setting surface gauge from the rule. Diagram (3) shows the correct method of taking measurements from a rule with a surface gauge. An angle plate holds the rule upright, so that the measurement taken from the rule will be true. The rule *must* be set vertically, or the reading will be wrong.

Taking measurements from a rule with calipers. Place index finger under end of rule to keep leg of calipers from slipping.

Diagram 4 shows the simplest method of setting calipers correctly from the rule with the least possibility of error. When setting inside calipers stand the rule vertically on some flat surface as shown in diagram (5). This will ensure a quick, accurate setting of the caliper when working from rule measurements.



MEASURING from RULE.

Accuracy of the rule. While the rule itself is accurate to a fine degree it is impossible to obtain a great degree of accuracy from its use, because it depends entirely upon the fine observations of the user. For this reason the vernier caliper and micrometer have been developed to guarantee mechanical accuracy to 1/1,000 and 1/10,000 part of an inch.

CUTTING METAL WITH A COLD CHISEL.

A cold chisel may be used in different ways to separate metal; one of the simplest methods of using it is in combination with the sharp edge of a vise. Another method of using the chisel is what is well known as "chipping". There are many different shapes of chisels which will be described later; at present, the simple functions of the chisel will be detailed.

Shape of cutting edge. The edge of the chisel is wedge shaped, the angle varying with the material being cut, 60° to 70° (see diagram (2)) being suitable for average work. If the chisel were ground straight as in diagram (1) the corners would soon wear round. Diagram (3) shows a far worse condition. Grind the chisel as in diagram (4) slightly convex, then the centre of the chisel takes most of the cutting strain and is well supported by the metal on each side. Its convex shape also gives a shear cutting action, making the cutting much smoother and easier.

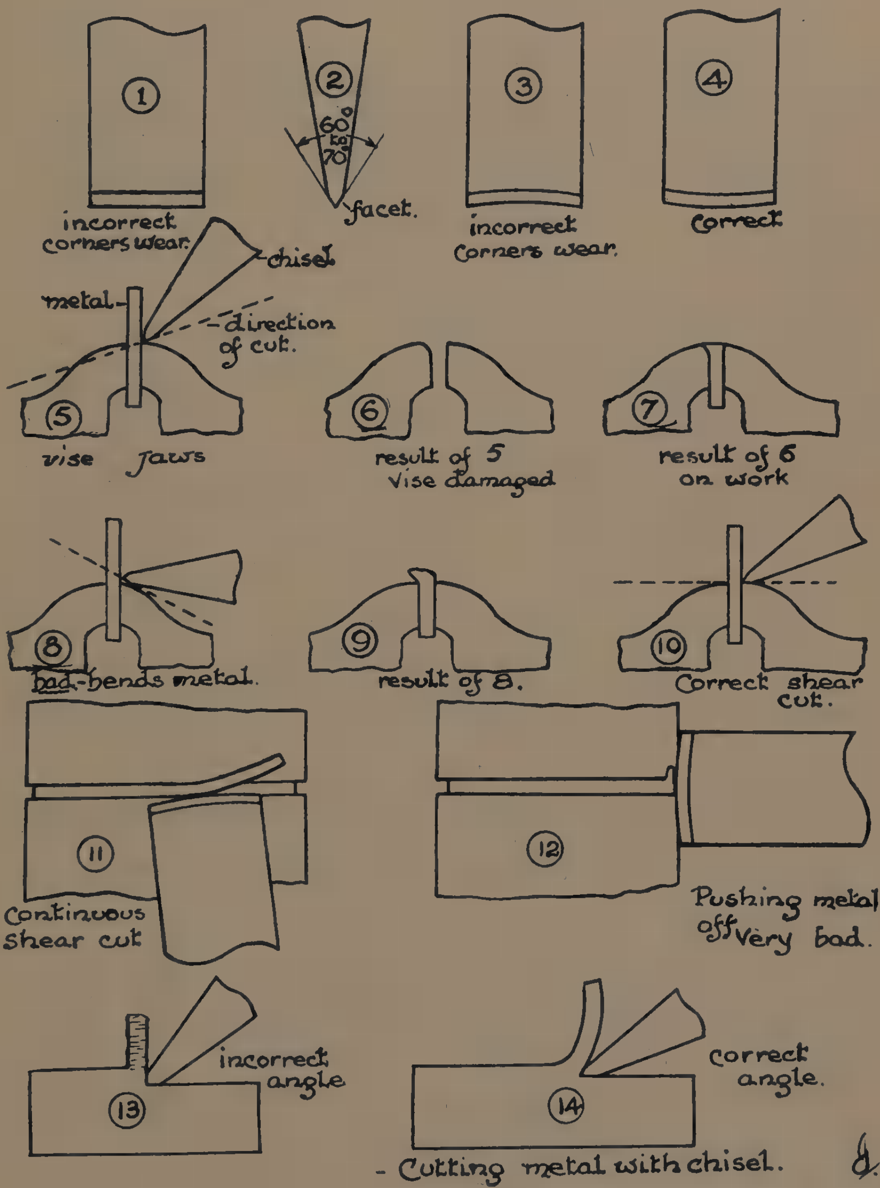
Use of the chisel. The beginner in using the chisel to cut metal in the vise is likely to do considerable damage to the chisel, vise and work unless precautions are taken to use the chisel properly as shown in diagram (10). The face or "facet" if held at the angle shown by dotted line in figure (5) will tend to cut in the angle as indicated and will cut into the back steel face of the vise, damaging both vise and chisel. If the vise edge is broken away as in figure (6) the metal cut in the vise afterwards will be spread or burred as shown in figure (7). On the other hand if the chisel is held so that the facet is inclined as in diagram (8), the metal will be pushed or torn off as shown in (9).

Great care, then, must be used to hold the chisel at the correct angle.

Shear cutting is produced by holding the chisel correctly as shown in diagram (10) this will leave a smooth clean cut on the work. On one side of the metal is the sharp cutting edge of the chisel, and on the other side the edge of the steel jaw of the vise.

To make a smooth continuous cut. It is necessary to incline the chisel slightly as shown in the top view (11). The chisel should never be held as shown in diagram (12), as it is unsuitable for thin metal and does not take advantage of the cutting edge of the steel vise jaw.

Chipping with chisel is shown in diagram (14), the metal itself offering resistance while the wedge shaped tool cuts it. Note the pushing action of the tool ground incorrectly in diagram (13). Chipping is usually understood to mean the removal of metal from broad surfaces by means of the hammer and cold chisel.


1
incorrect
corners wear.
2
60° to 70°
facet.
3
incorrect
Corners wear.
4
Correct
chisel.
metal
direction
of cut.
5
vise jaws
6
result of 5
vise damaged
7
result of 6
on work
8
bad-bends metal.
9
result of 8.
10
Correct shear
cut.
11
Continuous
shear cut
12
Pushing metal
off very bad.
13
incorrect
angle
14
correct
angle.
- Cutting metal with chisel.

THE FILE.

The file is one of the most important of all hand tools and is generally little understood and badly abused.

The beginner would do well to get a true conception of the file, its care, and the kind of file to be used for each purpose.

The file is a cutting tool with many teeth; it is made of high quality tool steel suitably hardened and tempered. The student should make himself familiar with the names of the parts of the file as shown in diagram (1). The tang is the only portion of the file that is soft, the rest of the file is very hard and if dropped on a hard floor it will possibly break.

The teeth of the file to-day are mostly cut by machine methods, but some years ago files were hand cut with a chisel as shown in diagram (3). The tooth of the file is formed by an incision into the soft metal with a sharp chisel-like tool which also pushes up the edge to form the tooth; afterwards the file is hardened and tempered.

Single cut files form one distinct classification of files. They consist of one single row of teeth usually from 65° to 85° angle, this inclination being given to obtain a shear cut. The single row of teeth give a smoother finish to the work than double cut teeth. The mill file is a single cut file.

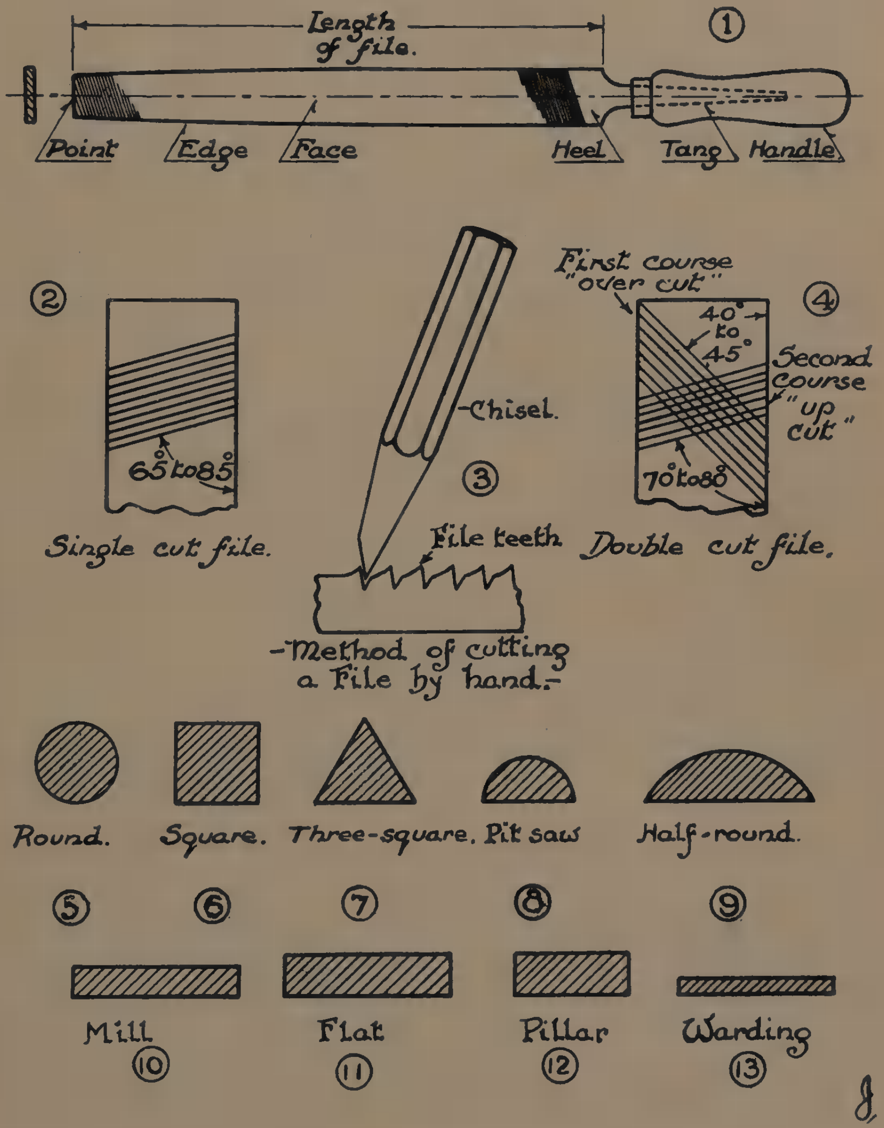
Double cut files have two rows of teeth crossing each other at opposite angles, the "over cut" teeth are cut first followed by the second course or "up cut" giving to the file teeth that are "points", whereas the teeth on the single cut files are chisels. Nearly all the files used by machinists can be obtained double cut.

Varying degrees of coarseness. The degree of coarseness or size of the teeth of the file is denoted by the names, bastard, second-cut and smooth. There are also coarser cuts known as rough and coarse, and a fine cut known as dead smooth used for fine finishing.

Form of files. A file is also selected by its shape in cross section as shown in diagrams (5) to (13). Files are selected by shape, size and fineness of cut. Files are classified principally by the coarseness and fineness of the cuts. There are two divisions of regular files,—saw files and machinist files.

Saw files are particularly adapted for sharpening saws and similar plate work for which double cut files are not suited. They are single cut and are usually bastard cut, second cut, and smooth cut.

Machinist files are usually double-cut and in degree of coarseness are rough cut, bastard cut, second cut and smooth cut. The mill file is an exception to this, being single cut and is suitable for filing lathe-work and for drawfiling as it leaves a smooth finish.


Length of file.
①
Point
Edge
Face
Heel
Tang
Handle
②
65° to 85°
Single cut file.
Chisel.
③
File teeth
-Method of cutting a File by hand.-
First course "over cut"
④
40° to 45°
Second course "up cut"
70° to 80°
Double cut file.
Round.
Square.
Three-square.
Pit saw
Half-round.
⑤
⑥
⑦
⑧
⑨
Mill
⑩
Flat
⑪
Pillar
⑫
Warding
⑬

FILING AND DRAWFILING.

The file, although a simply constructed tool, is in reality a difficult tool to use, and the beginner will find that to file well is an art which can only be acquired by practice. Some years ago the tradesman known as a "fitter" became very skilful in the use of the file by using it continuously, but to-day with work machined precisely to close limits the work of the fitter has practically gone.

To file thin metal. This operation is comparatively easy, because the work being filed is so narrow that its flatness and squareness are not very noticeable, the main object being to obtain a straight edge. It is easy to conceive from diagram (1) that to file square is almost a balancing operation for the person who holds the file. The moment p x d must equal the moment D x P at all positions of the file, and since the lengths D and d are continually changing, the work of keeping equilibrium or balance is a difficult one.

Drawfiling. After filing it will be noticed that the surface of the work is marked by serrations left by the file. If the file is held as shown in diagram (2) and operated in the direction of the arrows under light steady pressure, these irregular serrations or marks on the work will be removed and a fine finish with parallel serrations obtained. Greater accuracy can also be obtained by finishing work by the drawfiling operation.

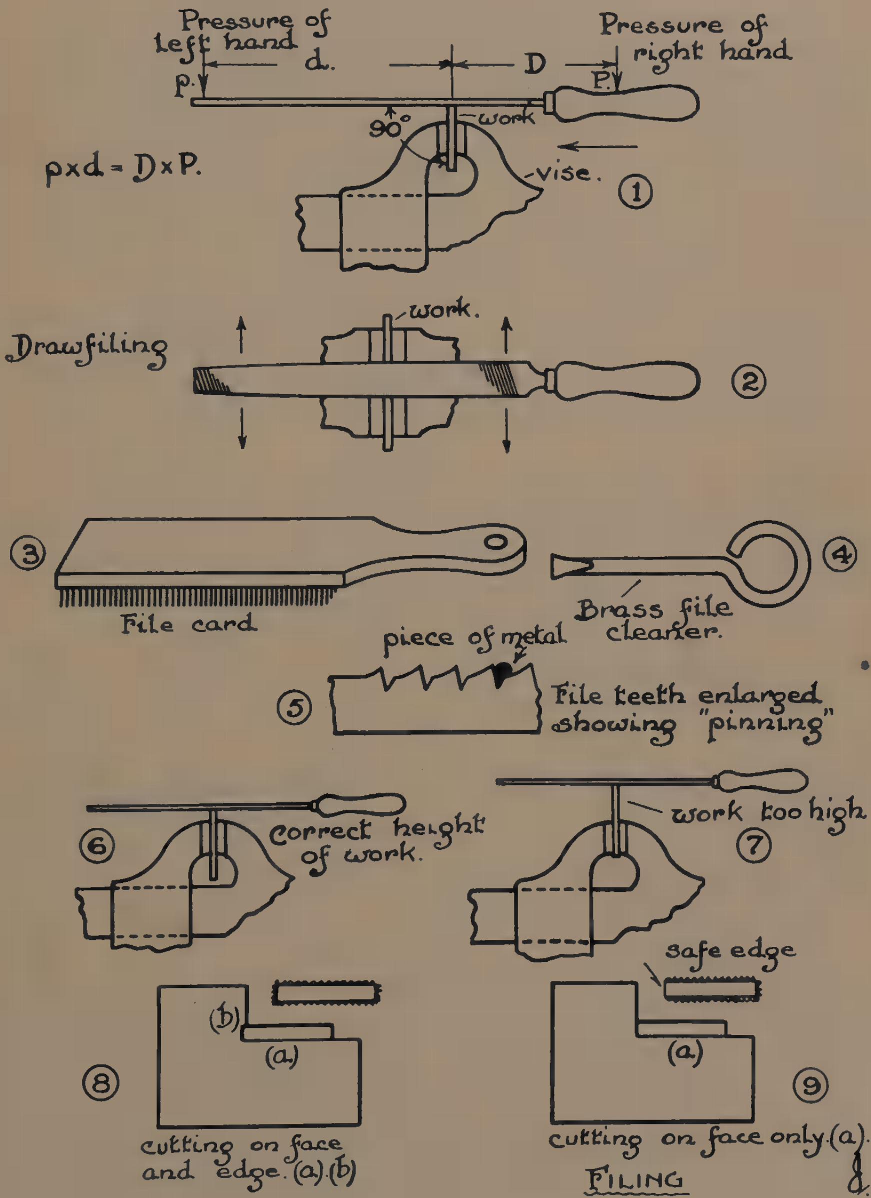
The file handle. It is very important to use only files provided with handles and to be sure that the handle is fitted tightly to the file. Serious accidents have been caused through this oversight.

To fit handle. Drill a hole in the handle, the average thickness of the tang, and heat an old file tang to a dull red and force in $\frac{2}{3}$ of its length; withdraw it quickly and cool the handle in water. Now fit the new file by tapping on the end of the handle until it fits tightly without splitting.

Pinning. Small particles of metal occasionally wedge themselves between the teeth of the file—this is known as "pinning" and causes scratches on the work. See diagram (5). Sometimes by rubbing ordinary chalk on the file it can be prevented. To remove the "pins" use a file card or push the "pins" out with a piece of flattened brass as shown in diagrams (3) and (4).

Height of work. The work face should be close to the top of the vise as in diagram (6), this gives rigidity to the work. If the work is high as in diagram (7) it is very noisy and springy producing a chattered surface.

Filing to a corner. If an ordinary flat file is used it will cut the work on two edges as shown in diagram (8), but if the teeth on the edge are ground off only the face of the file will cut as shown in diagram (9). This is called a "safe edged file."


Pressure of left hand
d.
D
Pressure of right hand
p.
P.
90°
work
vise.
p×d = D×P.
1
work.
Drawfiling
2
3
File card
4
Brass file cleaner.
piece of metal
5
File teeth enlarged showing "pinning"
6
Correct height of work.
work too high
7
safe edge
(b)
(a)
8
cutting on face and edge. (a).(b)
(a)
9
cutting on face only. (a).
FILING

THE HACKSAW.

The hacksaw is used for cutting metal and it is usually a very misused tool, owing to wrong selection of blades and incorrect handling. There are many different types of hacksaw frames, the "pistol grip" adjustable type shown in diagram (1) being perhaps the best. The saw blade is made of a high grade steel hardened and tempered. It is stretched in the saw frame to the proper tension to give it stability when cutting. The blade is fastened in the frame to cut on the forward stroke. The saw must not be used to cut too fast, 50 to 60 strokes per minute is about the right cutting speed for ordinary work.

Use of the saw. Slight pressure should be applied on the forward stroke as at A A and the pressure should be relieved on the return stroke as at B B, otherwise the teeth will be dulled. If the work is thick considerable pressure may be applied to make the teeth "bite", but if the work is thin or the material soft the teeth will likely catch and break the blade. Thin metal may be sawn by clamping it between two pieces of wood in the vise. A lubricant is unnecessary when using a hand hacksaw.

Number of teeth per inch. Saws are made with a varying number of teeth per inch and are selected to suit the work they have to do.

For general use in hand frames 18 teeth per inch.
Tool steel and cast iron 20 teeth per inch.
Tubing, brass, copper, drill rod 24 teeth per inch.
Thin sheet metal and thin tubing 32 teeth per inch.
Power blades for cutting soft steel 14 teeth per inch.
Diagrams (2) and (3) show comparative sizes of teeth.

The "set" of the saw. Diagram (4) shows the cut made by a saw with teeth "set" or set over alternately one each side to give clearance and freedom to the saw while cutting. Various methods of "setting" hacksaw teeth are shown in diagram (5). A is a wavy set each tooth cutting only part of the "kerf" or grove made by the saw.

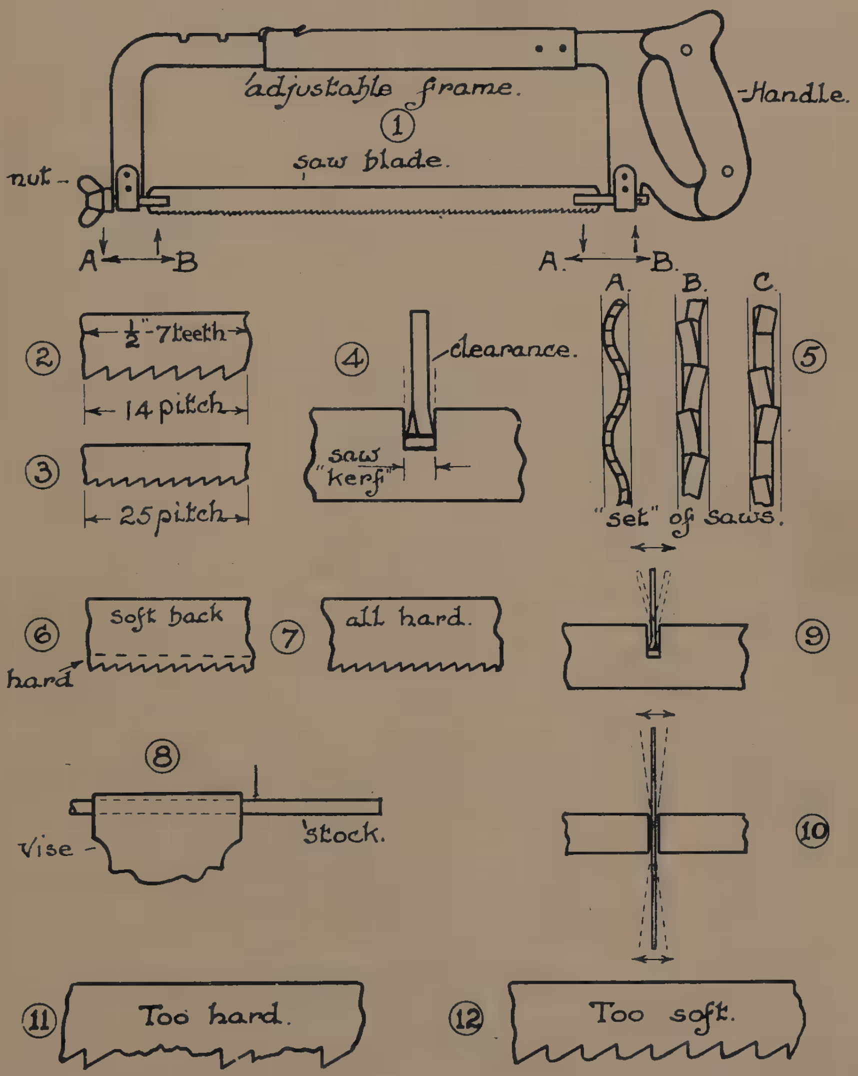
In diagram 5B each tooth cuts one half the "kerf". In 5C the teeth are set in threes each one of the three cutting its share of the metal.

Diagram (6) shows a flexible back blade or soft back, the teeth are hardened back to the dotted line, giving a flexible blade.

Diagram (7) shows a blade hardened throughout.

The work should be so placed in the vise so that most of the sawing may be done close to its jaw, as in Diagram (8); this reduces vibration.

Causes of blades breaking. One of the main causes of blades breaking is wrong selection, but improper and careless use breaks many blades also. If a saw blade is allowed to rock from side to side in use, as shown in diagram (9) it is likely to break. If the saw is not kept sawing in a straight line as shown in diagram (10) but allowed to move as shown by dotted lines it will break. When the teeth break as in diagram (11) it shows that the blade is too hard for the work it is doing. If the teeth are rounded as in diagram (12) it is obvious the teeth are too soft for that particular work for which it is used.



THE HACKSAW. 8

BENDING AND SHAPING.

In work at the bench it is often found necessary to make a simple bend in metal, and sometimes where several pieces have to be made it may be worth while to make up a simple "jig" which will save time and turn out work similar in size and shape. If metal will not bend cold with the assistance of levers it will be necessary to heat the metal to make it soft and pliable.

Bending flat stock. If a piece of flat stock 1″ x ⅛″ is taken it will be noticed that it is quite an easy matter to bend it flatwise, but if it is bent edgewise it is difficult to bend and will wrinkle up unless a special bending block is used. In diagram (1) A A represents the axis of a piece of metal. If the metal is bent A A will not be compressed or extended. Outside the neutral axis B B is extended when bent, and inside the neutral axis C C is compressed. Under these stresses the metal will seek relief and wrinkling will take place, this would have to be corrected with the hammer or some other mechanical device.

Simple bending. Right angles may be bent in the vise with the hammer as shown in diagrams (3) and (4). If the metal is likely to spring back after bending the position shown in (3) is used, so that the metal can be bent slightly beyond the right angle.

Simple punch and die, as shown in diagram (5), is suitable for making a simple cap for a clamp and will illustrate the action of a punch and die and its influence on the metal. The blank fits into the recess of the die, but when it is punched the diameter is reduced as shown by the dotted line showing that the recessing to the form has drawn the metal in radially.

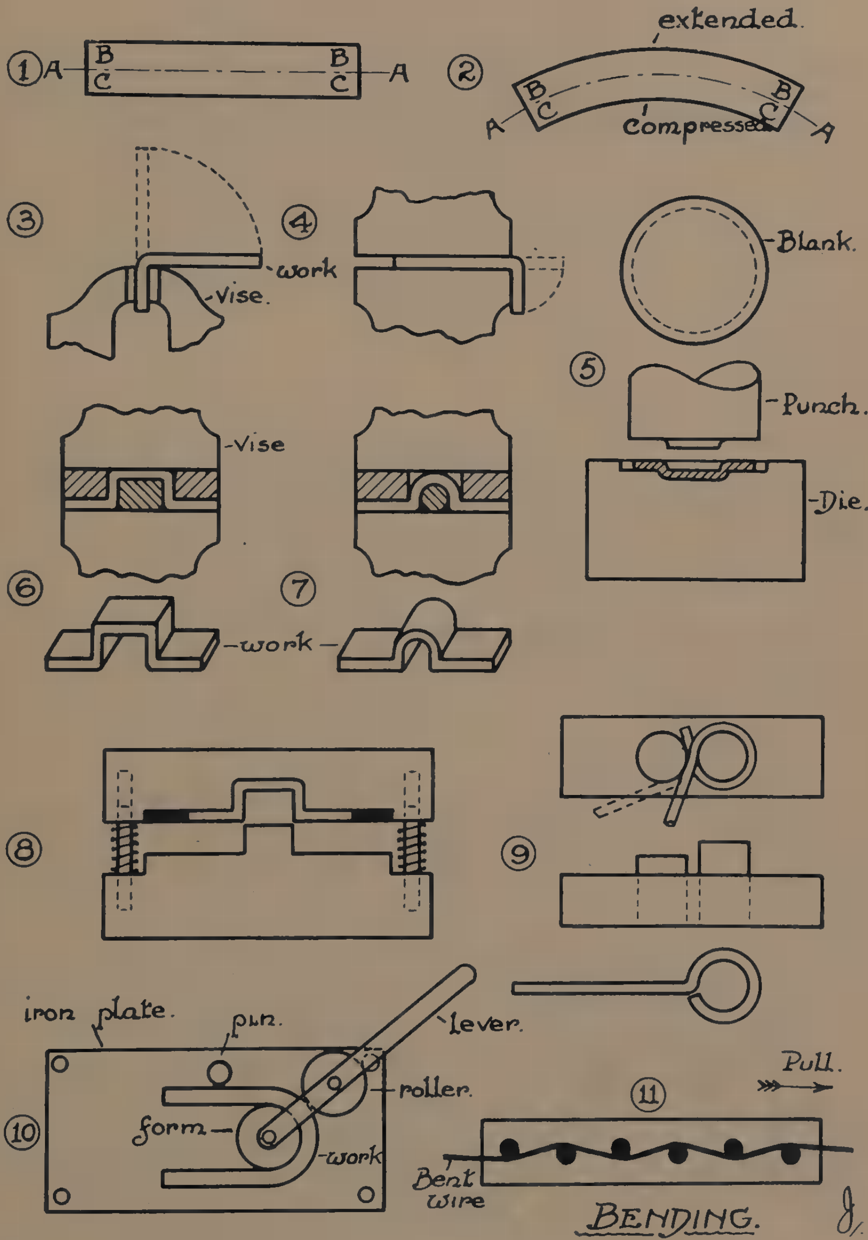
Pressing metal in vise by the squeezing action of the jaws is shown in diagrams (6) and (7). Suitable pieces of metal being used to give the required shape and size to the form required.

Bending jig. A simple spring bending jig is illustrated in diagram (8) This could be operated between the jaws of a vise and is very suitable for producing a number of simple bent parts.

Bending eyes. The simple bending jig shown in diagram (9) is held between the jaws of a vise. One pin is lower than the other to allow the wire to pass over it to make a circular bend. The straight piece is cut off when the bend is made and the metal is flattened.

Heavy bending. A bending block shown in diagram (10) is used for bending heavy metal. The lever and roller making the operation comparatively easy.

Straightening wire. To straighten wire by hand or with a hammer and block would take too long. If a simple jig as shown in diagram (11) is used the wire can be pulled through it and is straightened very quickly.


1
A
B
C
B
C
A
2
extended.
B
C
B
C
A
compressed
A
3
work
vise.
4
Blank.
5
Punch.
Die.
Vise
6
7
work
8
9
iron plate.
pin.
lever.
roller.
form
work
10
11
Pull.
Bent wire
BENDING.

THE STOCK AND DIES.

A stock and die is used to cut a thread "by hand", but most threads used in manufacturing are cut with dies in screw machines and bolt machines. The stock is provided as a turning device for the die, the long handles by their lever action making the operation easy for the operator. It is better to use a cutting compound such as lard oil to give easy cutting and produce smooth threads. There are many styles of dies in use, a familiar type being shown in diagram (2). When the dies become worn new ones can be obtained at a very small cost.

Diagrams (3) and (4) show two sectional elevations of a die and diagram (5) shows the plan. The die consists of the outer part called the *Collet*, the lower part called the *guide*, the *dies* themselves and the *adjusting screws*.

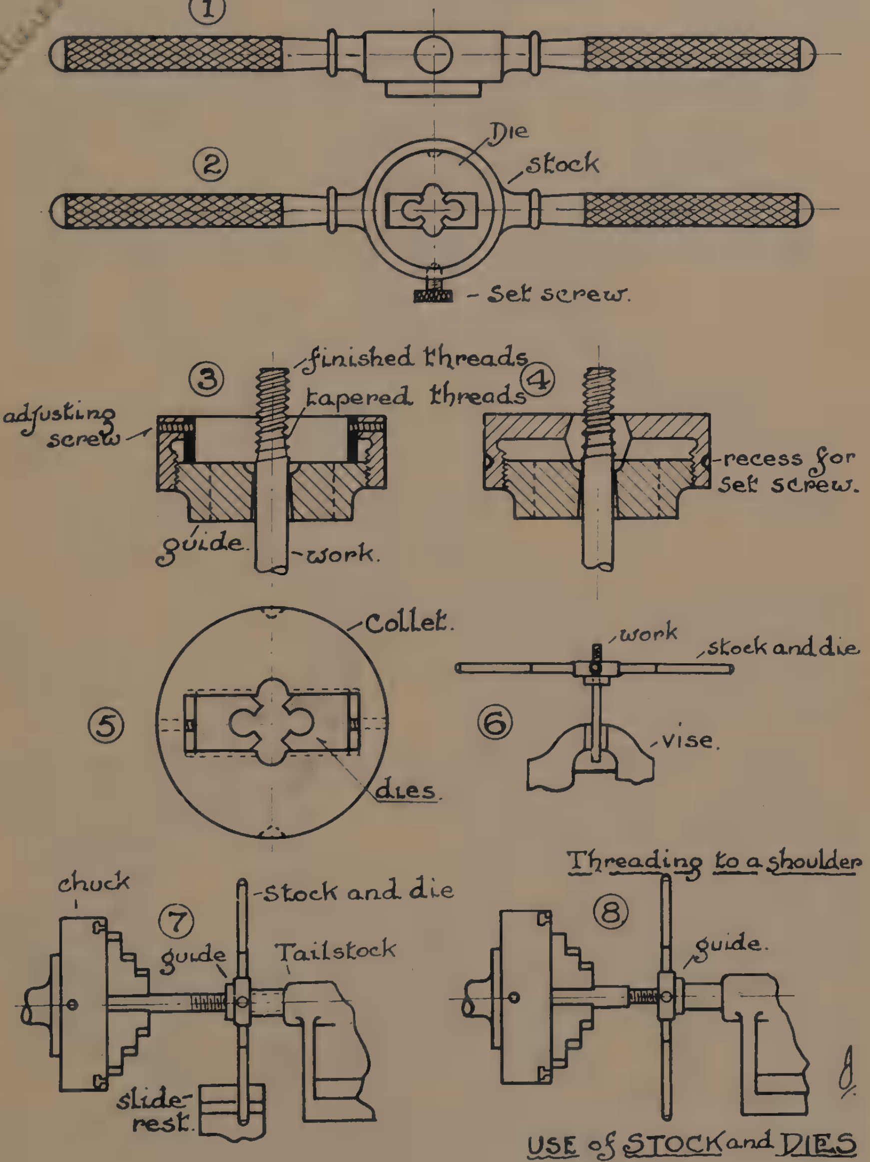
The collet. Has a threaded recess beneath, into which the guide is tightened to support the dies and hold them against the tapered seat. This keeps the dies exactly opposite each other. The collet has two conic recesses at opposite sides into which the set screw of the stock fits, to prevent the die turning in the stock while the threads are being cut. Care should be taken not to put the collet in the stock upside down, otherwise the set screw will cut the collet and will not hold it securely.

Assembling the dies in the collet. All the parts should be clean before assembling, because if a small metal chip gets between the dies and the collet or the guide and the dies, although the guide may be tight, the dies will probably be out of line with each other and the threads on the work will be spoilt.

Adjustment of the dies. The type of die represented in diagram (3) is adjustable to size, that is if the stock were over 3/8″ diameter the dies might be set to fit it and still cut threads. But the threaded piece would be too large to fit a hole threaded with a 3/8″—16 tap. Similarly the dies may be set too close and threads may be cut on the work which would fit very loose. It is much better if suitable marks are provided to show when the dies are set to cut the correct size. The adjustment of the dies may be used to advantage in cutting large threads in two cuts.

Diagram (6) shows the usual method of threading work "by hand" by holding the work vertically in a vise. The work should be slightly bevelled to give the die an easy start. Notice in diagram (3) that the under side of the die has tapered threads to start easily and care must be taken to see that the die cuts slightly beyond the amount required to prevent having tapered threads on the end of the work.

Diagram (7) shows the method of threading work in the lathe, and diagram (8) shows how the die has to be used the reverse way when finishing threads to a shoulder.


①
②
Die
stock
Set screw.
③
finished threads
tapered threads
④
adjusting screw
recess for set screw.
guide.
work.
Collet.
⑤
dies.
work
stock and die
⑥
vise.
Threading to a shoulder
chuck
⑦
Stock and die
guide
Tailstock
slide-rest.
⑧
guide.
USE of STOCK and DIES

HAND TAPPING.

Before tapping a hole it is necessary to look up a suitable table of tap drill sizes, or calculate the size of the hole. Tapping is an operation that should not be undertaken until the beginner has a clear conception of the elementary points dealt with here.

Set of taps. Diagram (2). Hand taps over ¼″ diameter are made in sets of three, known as "Tapper Tap", "Plug Tap", "Bottoming Tap."

The taper tap is tapered at the end at least six threads from the point and is used for starting all tapped holes, and for the majority of holes it is the only tap required.

The plug tap is tapered at the end about three or four threads and is used to follow the operation with the taper tap when putting threads to the bottom of a "blind" hole.

The bottoming tap has full threads throughout and is used as a finishing tap to cut threads to the bottom of a hole.

Relief of taps. Taps have 3 or 4 "flutes" or grooves and the lands are relieved at the back of the cutting edge to prevent friction and binding. One third of the land at the back of the cutting edge is the nominal shape and size of the thread, so that the top may be sharpened by grinding the flutes leaving the tap full size.

Adjustable tap wrench (1) is fitted to the square shank of the tap, and is operated at first with a steady downward pressure until the tap is well started. It is then necessary to work the tap backwards and forwards half a turn each way to break the chip and make the thread smooth. Use lard oil when tapping iron and steel, but cast iron is tapped dry. The tap wrench gives a distinct mechanical advantage so that care must be taken not to break the tap.

Tap drill sizes. Diagrams (3) and (4) show the comparative tap drill sizes for a U.S.S. (United States Standard) and a S.A.E. (Society of Automotive Engineer's). Both holes are drilled for the same diameter screw, but the U.S.S. thread has a coarser pitch than the S.A.E., therefore the hole for the S.A.E. is drilled larger.

Diagram (5) shows an enlarged thread of the U.S.S. form. The diameter of hole drilled for tapping should be greater than the root diameter of thread to give easy tapping. Two-thirds the double depth of thread is sufficient to allow for tapping. If only one-half the full thread were allowed the bolt would break before the threads were stripped, so that it is not advisable to have screws fitting too tightly unless specially desired.

To find tap drill size. For full depth of U.S.S. thread divide the constant 1.299 by the number of threads per inch.

For ⅔ depth of thread ⅔ of 1.299—.866 or .9 approx.

Example ⅜″ tap 16 threads.

Solution ⅜″—⁹⁄₁₆=.375″—.056″=.319″.

Tap Drill Size=.319 or ⁵⁄₁₆″ approximately.

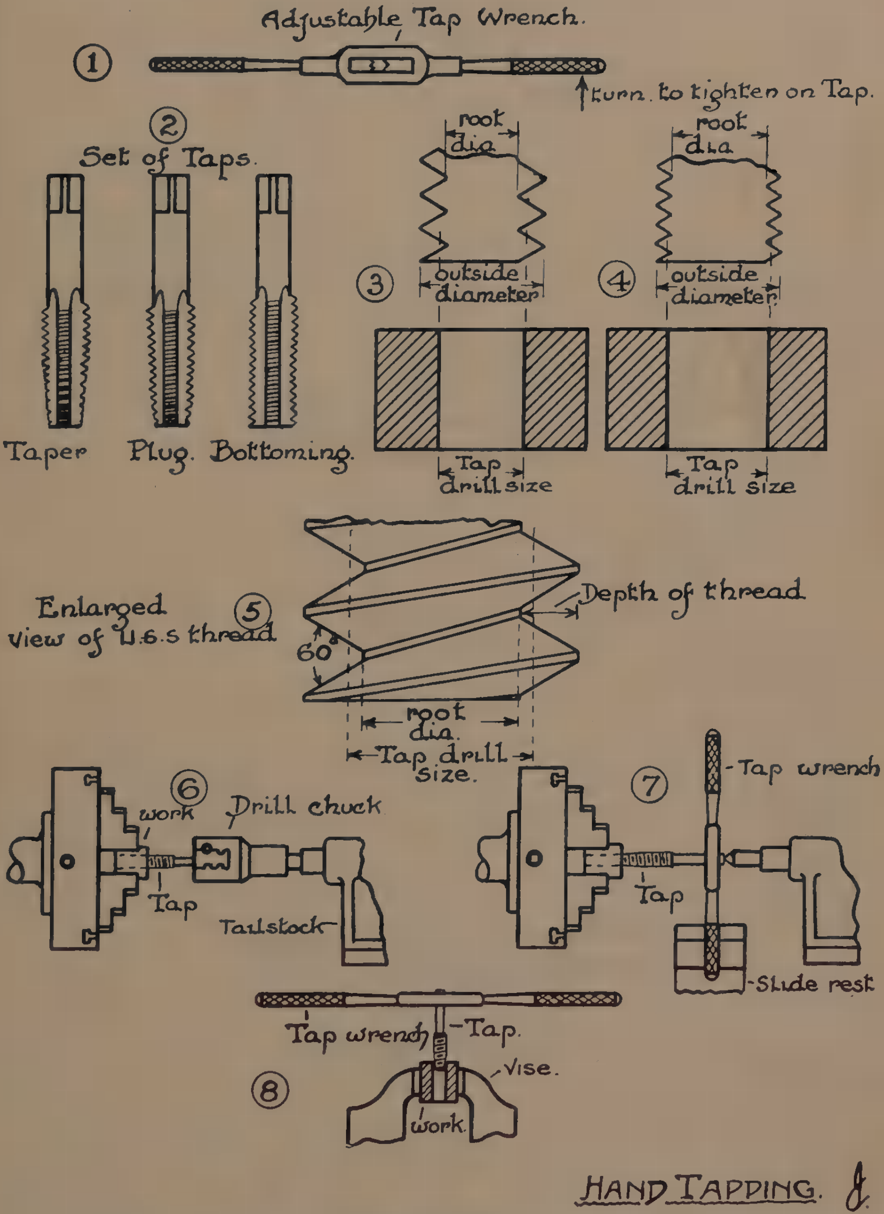
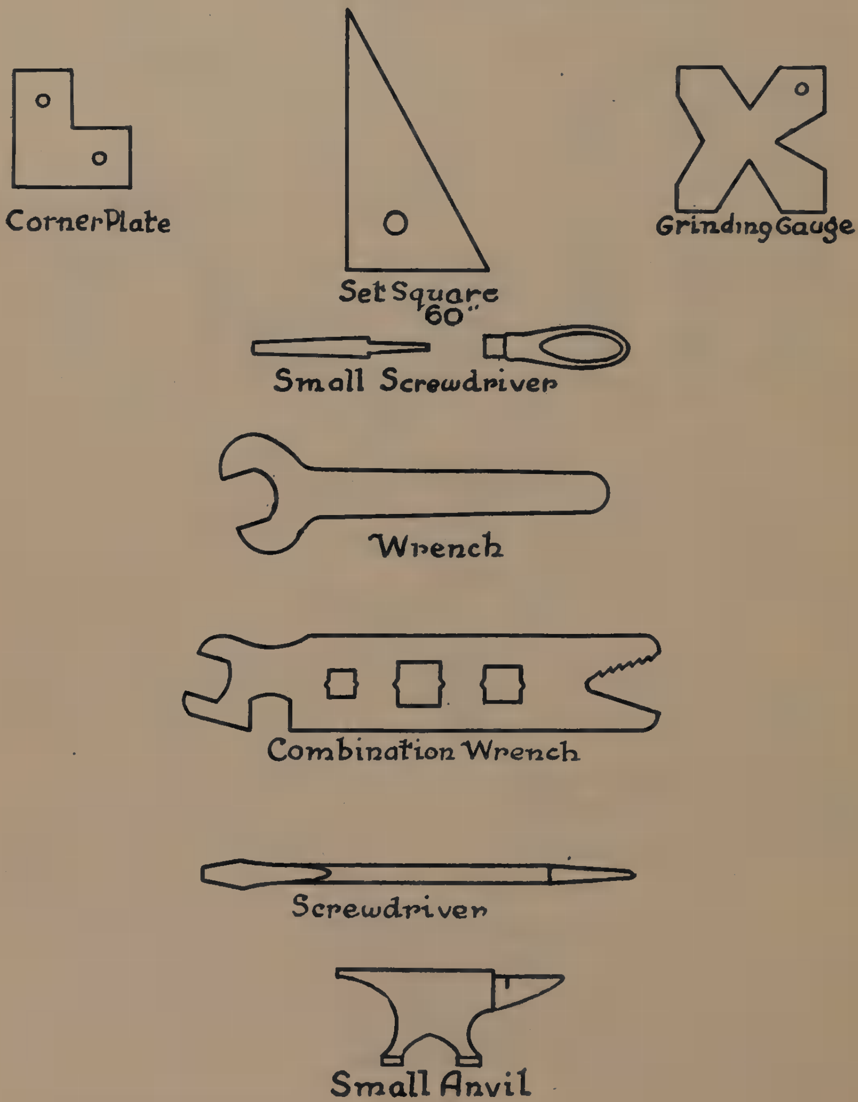


Diagram (6) *and* (7) show methods of starting tap in alignment by using the lathe, it is very important before doing this to see that the tail-stock is not set-over.

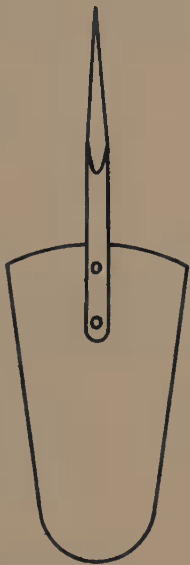
Diagram (8) shows the method of hand tapping in the ordinary way by holding the work in the vise.

PROJECTS

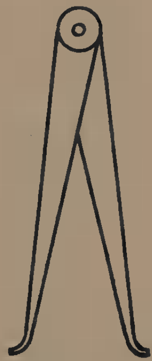


Laying out, Cutting with chisel, Filing, and Drilling

Picture Hanger



Trowel

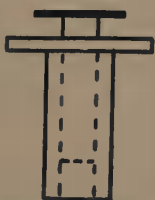


Inside Calipers

Slide for Inclined Table Top

Bill File

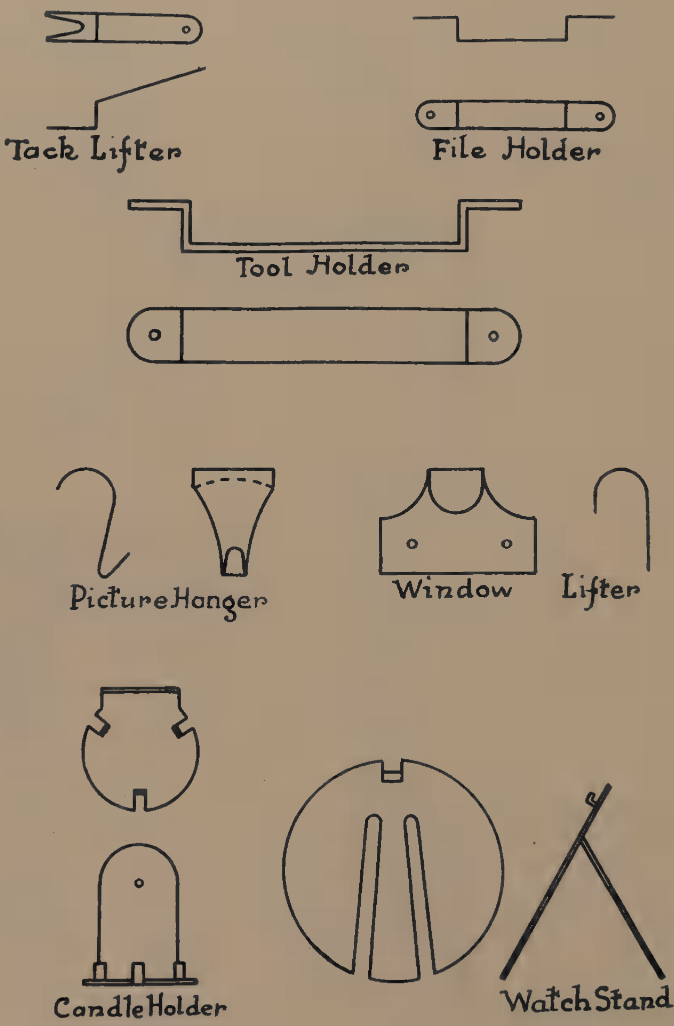
Square



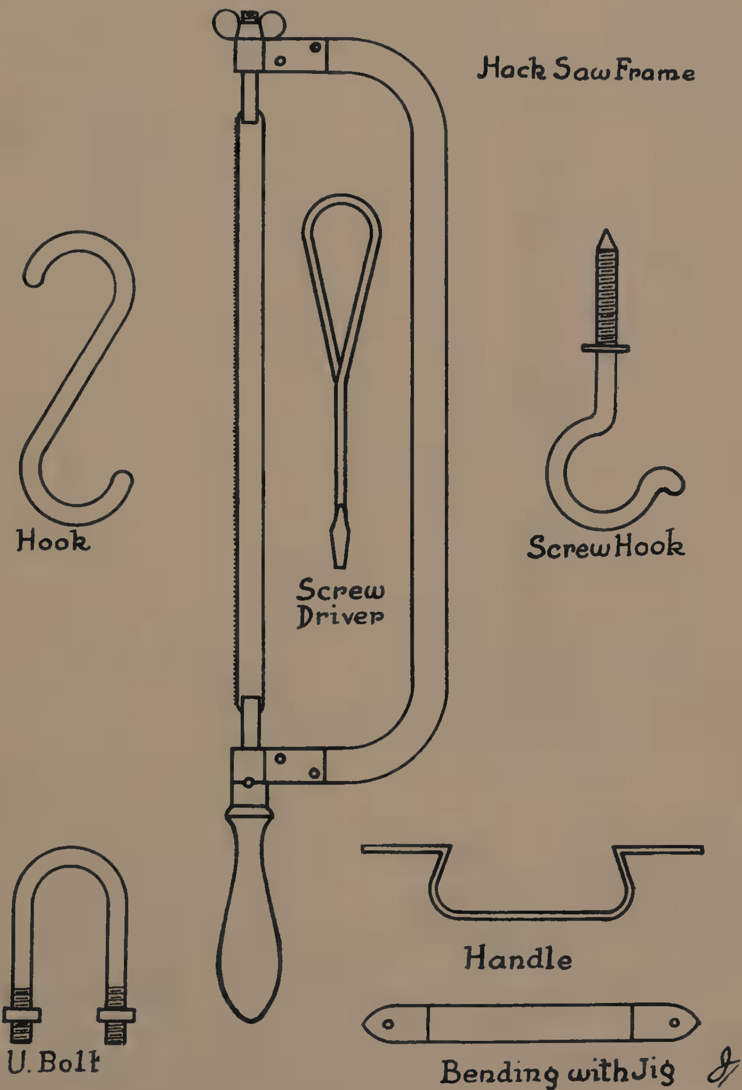
Bench Stop (Adjustable)

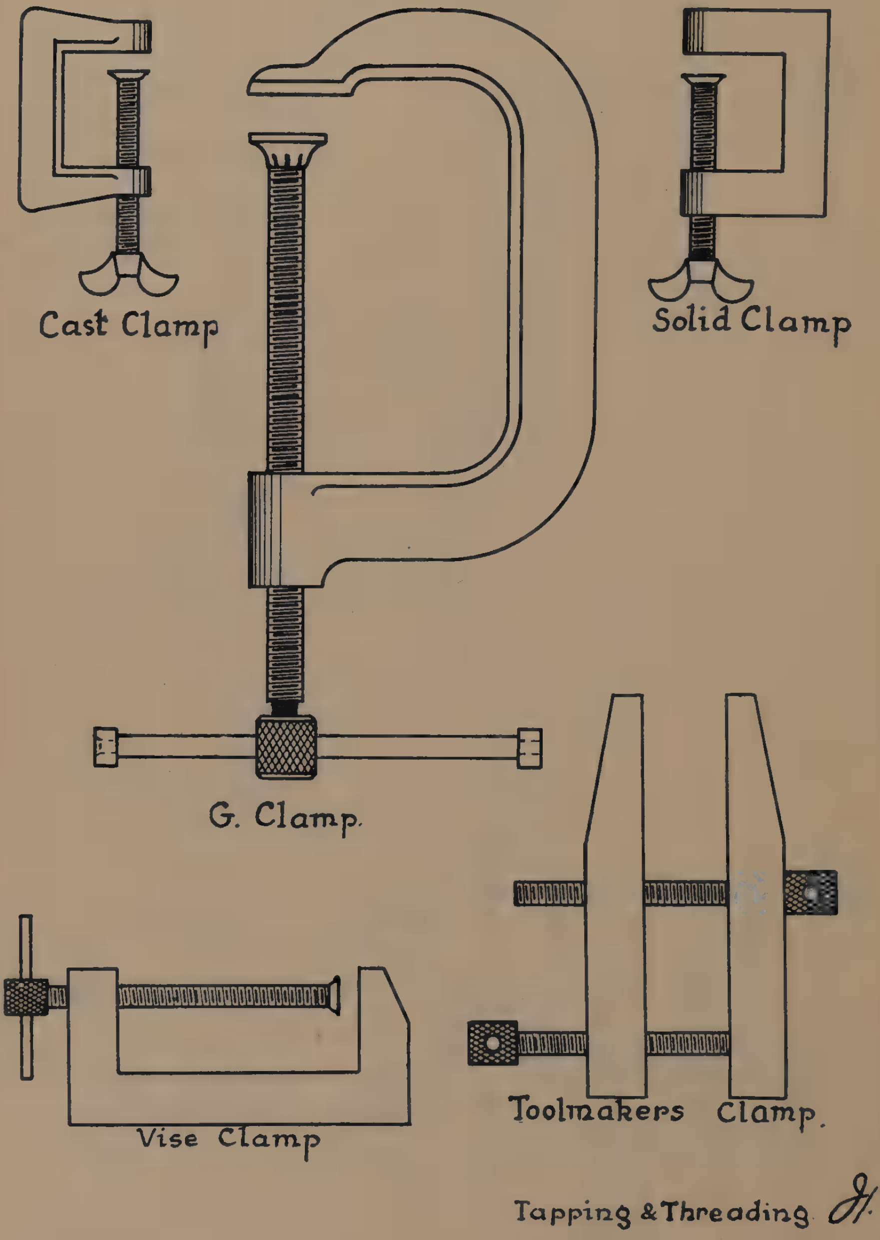
Rivetting

PROJECTS



Simple Bending


Hack Saw Frame
Hook
Screw Driver
Screw Hook
Handle
U. Bolt
Bending with Jig


Cast Clamp
Solid Clamp
G. Clamp.
Vise Clamp
Toolmakers Clamp.
Tapping & Threading J.T.

QUESTIONS ON BENCHWORK.

1. What substance may be used on the surface of metal before laying out? Why is this necessary?
2. What solution is used on surfaces which have been machined?
3. Why is it necessary to mark lines with a punch when laying out?
4. What precautions must be taken in using a scriber and a centre punch?
5. Why is it necessary to make a deep punch mark for the centre of a hole which has to be drilled,
6. What particular care is necessary in laying out measurements from a rule?
7. How would a rule be placed when setting a surface gauge to a dimension?
8. How would a pair of calipers be placed in setting them to size from a rule?
9. What is the correct manner of grinding the cutting edge of a cold chisel?
10. Why must the face or faucet of a cold chisel be in a horizontal position when cutting metal in a vise?
11. What do you understand by a "shear cut" when using a cold chisel to cut thin metal in a vise?
12. How is the length of a file measured?
13. What do you understand by a "single cut" file, and a "double cut" file,
14. How is the degree of coarseness of a file expressed?
15. What are the common shapes of files?
16. Why is it difficult to file a surface flat?
17. What do you understand by "drawfiling"?
18. How would you try to prevent a file from "pinning"?
19. How is a file cleaned?
20. How would you hold work in the vise to file it?
21. What do you understand by a "safe edged file"? When is it used?
22. How is a hand hacksaw blade fastened in a saw frame?
23. What do you understand by "pitch" in reference to saw teeth?
24. What is the "set" of a saw? Why is it necessary? What are the forms of "sets" commonly used?
25. What are some of the causes of saws breaking?
26. What saw blades would you select for sawing the following: Tool steel, cast iron, tubing, brass, thin sheet metal?
27. What occurs in a piece of metal when it is bent?
28. What simple bending devices do you know of?
29. Name the parts of an ordinary stock and die.
30. What different ways can a stock and die be used?
31. How would you thread to a shoulder with a die?
32. Why are dies made adjustable?
33. Why is it necessary to clean a die before using it?

DRILLING

THE DRILL PRESS.

The drill press like all other machine tools must be understood before it can be used efficiently. Many of the mistakes made in drilling are due to a lack of knowledge of the machine and the tools used with it. Any person who has drilled holes with a hand drill or breast drill realizes that there are two essential points in good drilling, to hold the drill steady and true in correct relation to the work and to hold the work firmly in relation to the drill. The drill press is designed to give varying cutting speed to the drill, to keep the drill steady in rotation and to provide suitable support for the work.

The drill press base is bolted to the floor and supports the column of the drill. Often the base of the drill press is tee-slotted, so that large work may be bolted to it while the table is moved to one side.

The Column is accurately machined and keeps the table at right angles to the column in the various positions in which it may be used.

The table can be raised or lowered by turning the handle operating the elevating screw. When the table is in the position required it is clamped rigidly to the column. Holes are made in the table which should be placed beneath the drill to prevent the table being spoiled by careless drilling. The table is provided with tee slots into which tee bolts may be used with suitable clamps to hold down work rigidly while it is being drilled. Work should never be drilled unless it is held solidly with the machine. The table may be swung sideways to accomodate various kinds of work and bring holes into their proper position for drilling.

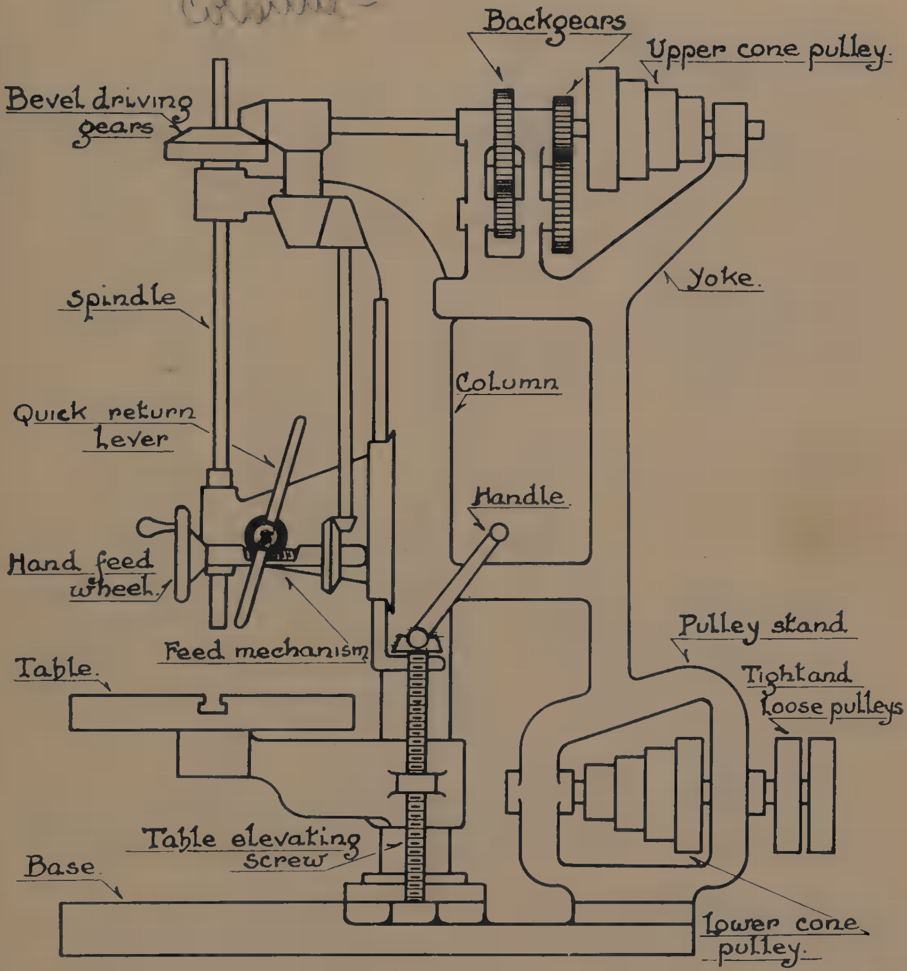
Fast or tight and loose pulleys are usually provided to receive transmission by belt, and a foot lever usually pushes the belt on or off these pulleys. If the belt is on the tight pulley the machine is running, if on the loose pulley the machine is stationary and the pulley runs free.

The speed cone provides a variety of rotating speeds similar to a lathe, and if the machine is back geared there is a further range of speeds.

The spindle obtains its rotation through bevel gears which change the direction of rotation at right angles from the upper shaft on which the upper speed cone is placed. The spindle, which carries the drill or other cutting tools, revolves in a fixed relative position in a sleeve, which does not revolve, but which slides up or down giving the feed to the spindle and drill.

The feed. A feed mechanism is provided which gives a steady movement to the drill into the material. It is generally better to use a steady mechanical feed than to operate the feed through the hand wheel provided, but sometimes a hand feed may be desired.

Types of drilling machines. Upright Drills similar to the one illustrated here, Post Drills, Radial Drills, Horizontal Drills, Gang Drills, Multiple Drills, Sensitive Drills, Portable Drills.



THE DRILL PRESS

DRILLING SMALL HOLES IN THIN METAL.

One of the first operations for a beginner will be to drill holes less than ½″ in diameter in comparatively thin metal. To do this efficiently and safely it is necessary to have at least an elementary knowledge of the parts and use of a standard upright drill press and the method of holding and driving small drills.

Speed of the drill. It is necessary to decide upon a suitable speed for the drill being used. If drills are of such comparative sizes as shown in diagrams (1) and (2) it is obvious that the small drill must run faster than the larger drill to obtain the same cutting speed. It is advisable therefore to calculate such speeds in revolutions per minute from recommended cutting speeds for a given material in feet per minute or look up the speed in a table of drill speeds for the size of the drill and material being used. See page—

Types of drills. It should be known whether the drill being used is made of carbon steel or high speed steel as the latter can run at almost twice the speed of the former. If a carbon steel drill is run too fast the corners will be rounded and it will heat up, thus drawing the temper and ruining the drill.

Drills having parallel shanks are made in the following sets:—

(1) Number sizes No. 1 (.228 dia.) to No. 80 (.0135 dia.).

(2) Letter sizes A (.234 dia.) to Z (.413″ dia.).

(3) Straight shank drills 1/64″ to ½″ by 64ths.

Drills having taper shanks are made ¼″ to 4″ in diameter, increasing by 32nds on small sizes and 16ths and 8ths on larger sizes.

Metric sizes are from 4 m.m. (millimetres) to 50 m.m., increasing by 1 m.m. on small sizes and 5 m.m. on the larger sizes.

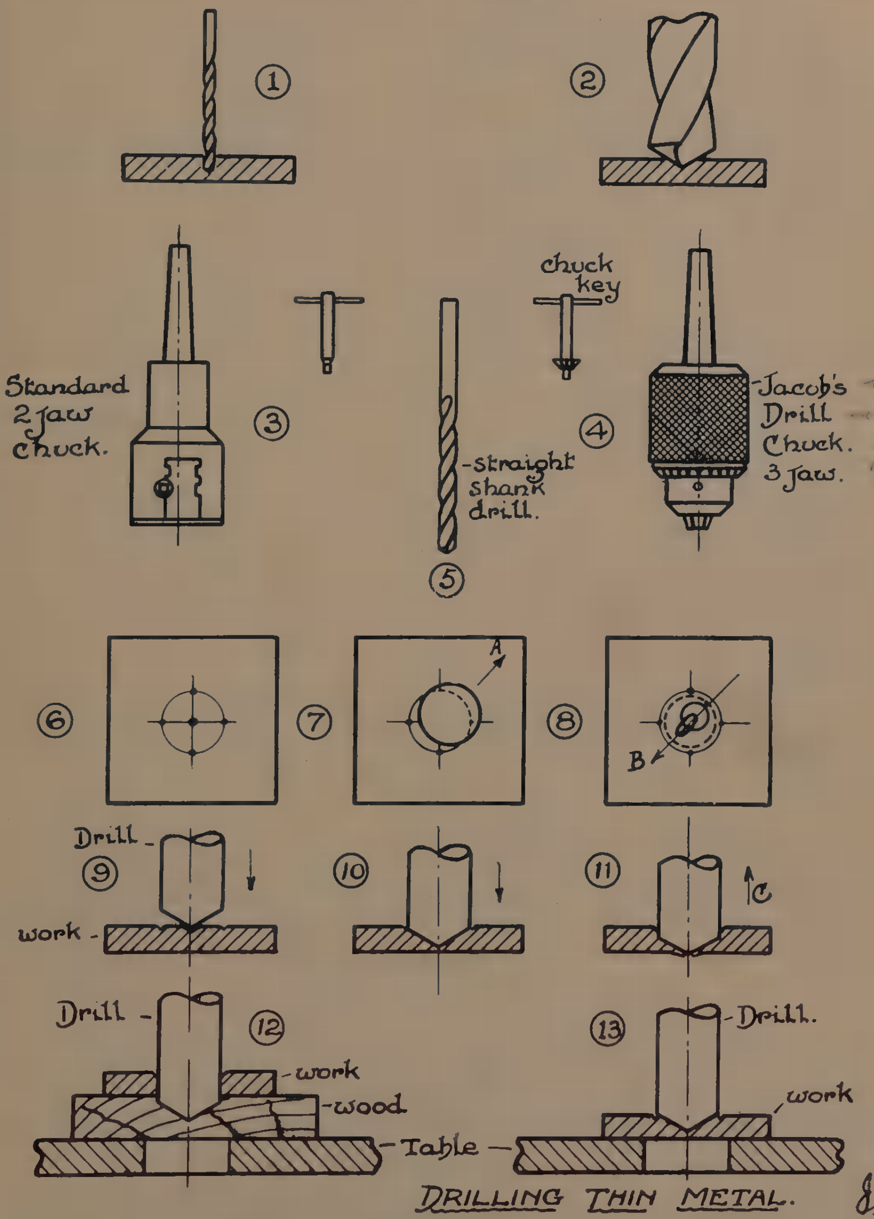
Smaller drills are not marked and the size is found by using a drill gauge which is a plate of metal with a series of holes and with sizes stamped near the holes.

Chucks used for straight shank drills. These are shown in diagrams (3) and (4). *The Jacobs chuck* shown in diagram (4) is a 3 jaw chuck adjusted first by hand with the knurled nut then tightened securely by the key.

The standard [illegible] jaw chuck has interlocking parallel jaws and is adjusted by a plain chuck key.

These chucks are fitted with morse taper shanks which fit into a corresponding tapered hole in the spindle.

Drilling the hole. After laying out the hole as in diagram (6) the drill will not always drill in the correct location as shown in (7) due to various reasons. (a) Drill may not be correctly ground (b) work may not be held stationary (c) irregularities in the fitting of the machine itself. If the tendency to run off as shown in diagram (7) is noticed, before the full diameter of the drill is reached, it may be corrected by cutting a groove as shown in diagram (8) by means of a diamond point or a round nosed chisel. This will allow the drill to cut back in the direction B. As soon as a correct location is seen as shown by dotted line the



hole can be drilled through. Diagrams (9), (10) and (11) show stages of drilling a hole in metal. Hold back on the feed, as shown by the arrow C in the diagram (11) as the drill penetrates the metal. Diagrams (12) and (13) show the drill cutting into wood or passing into the table hole after penetrating the metal, to prevent damaging the drill point.

DRILLING HOLES IN THICK METAL.

The straight shank twist drill shown in diagram (1) is commonly used for all small size drills. It is driven by being fastened in a parallel-jawed chuck, which in turn is driven from the drill spindle to which it is fastened by its tapered shank (see page 33). The friction between the jaws of the chuck and the straight shank of the drill is usually sufficient to drive it, but if the resistance of the material being drilled is too great the chuck will slip on the drill shank.

For holes of large diameter *a taper shank drill* is used (diagram 2). *Note*: See page (37) on drill shanks.

The sleeve, shell socket or collet is used to increase the size of a tapered drill shank. If a drill press spindle has a No. 3 morse tapered hole and it is required to fit a drill with a No. 2 morse tapered shank it would be necessary to enlarge the drill shank to make a fit. To accommodate the drill to the spindle a sleeve is used with a No. 2 morse taper hole in it to fit the drill and a No. 3 morse taper on the outside to fit the drill spindle.

The drill socket (diagram 4) can be used in a similar manner to a sleeve but in addition to that occasionally it is necessary to fit a No. 4 taper shank drill to a drill spindle with a No. 3 hole; and this would be impossible, without the use of a socket. The socket required to satisfy the conditions stated would have a No. 3 morse taper shank shown at A to fit the drill spindle and a No. 4 morse tapered hole shown at B to fit the drill.

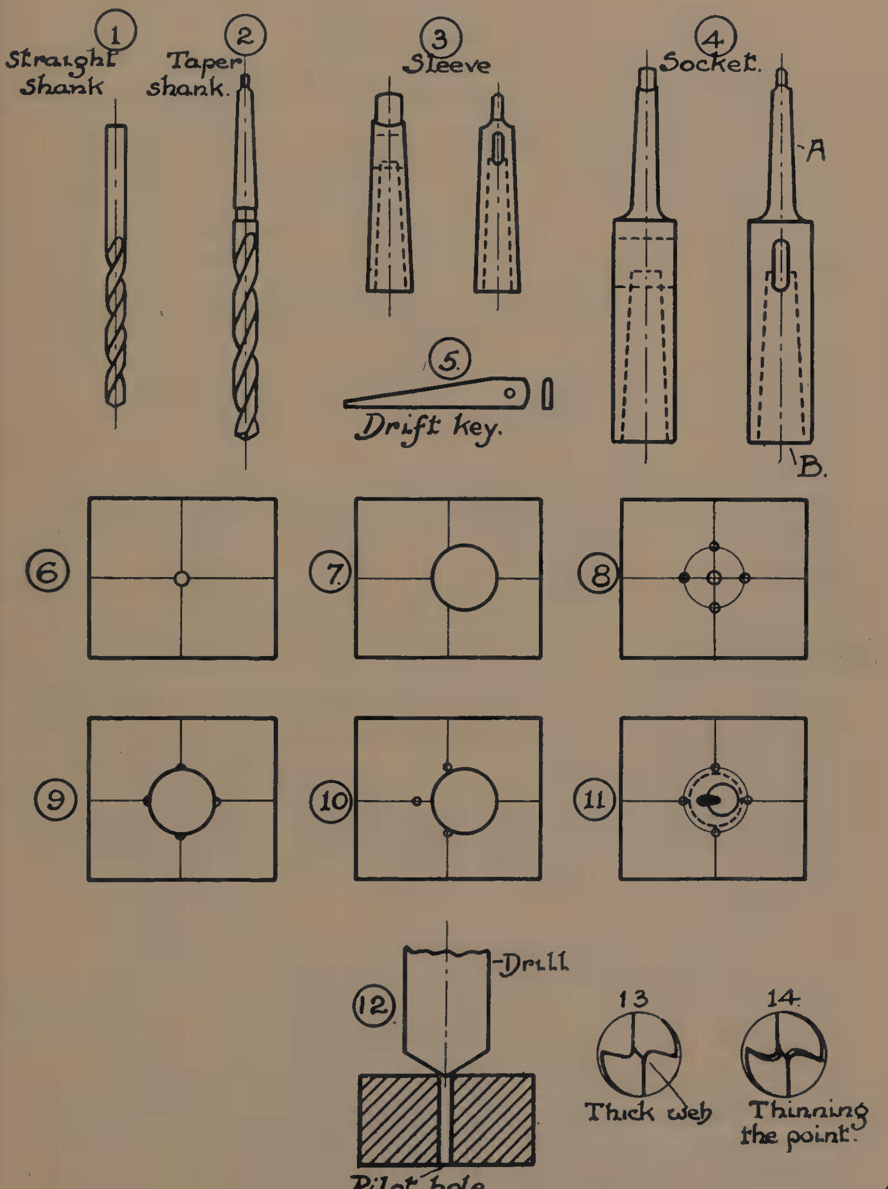
The drift key. After a taper shank drill has been fitted to a drill spindle, sleeve or socket, it is necessary to drive a tapered drift key into the slot provided to loosen it. Notice that one side of the drift key is flat and the other round. The round side fits against the upper round part of the slot in the spindle, sleeve or socket and the flat part fits against the end of the tang being removed.

To drill a hole in its true location. Diagram (6) shows the centre of the hole marked with a centre punch. If this hole were drilled the only permanent record of the location of the hole would be removed as shown in diagram (7). The hole therefore should be laid out as shown in diagram (8), so that when drilled as shown in diagram (9) evidence of true drilling remains or a proof that the drill is off its correct position as in diagram (10).

To correct a drill when cutting off centre. Diagram (11) shows a drill cutting off centre. To correct this cut a groove with the centre chisel on the side to which the drill is to be drawn and when the drill is cutting concentric with the outer line as shown by the dotted line the hole can be finish drilled.

Drilling with large drills. Large diameter drills have thick webs and it is advisable to drill a pilot hole as shown in diagram (12) to make a free and easy passage for the drill.

Thinning the web. Drills with a thick web as shown in diagram (13) are sometimes thinned by grinding as shown in diagram (14) to make easy cutting at the drill point.



DRILLING THICK METAL

TYPES OF DRILLS.

A drill must have the following characteristics:—

(1) It must have one or more cutting edges.

(2) It must have a central guiding or leading point, which is usually obtained by grinding the cutting edges at an angle with the axis of the drill.

(3) The cutting edge must have sufficient clearance behind it.

(4) A suitable shank must be made on the drill for driving it.

The taper shank twist drill, diagram (1). This is one of the common drills used, the flutes or spiral grooves provide a means of removing the cuttings from the hole away from the cutting point. The inclination of the flutes at the cutting edges provide a similar angle to the front rake of a lathe tool, thus tending to force the drill into the work. A drill has a slight clearance on the body, being slightly larger at the point than at the shank end to prevent binding in the hole. The web of the drill is thicker as it approaches the shank end to make the drill strong at the point of greatest strain.

The lands of the drill have a portion concentric and the remainder eccentric to give relief to the lands.

The straight fluted drill, diagram (2), is much used for drilling the softer metals such as babbitt, brass and other copper alloys. It is also very suitable for drilling thin metal owing to the fact that the chip pressure acting on the flat face of the flute does not give to the drill the pulling-in tendency noticeable in the twist drill. The twist drill is more suitable for materials that offer much resistance to the cutting action of the drill.

Diagram (3) shows an ordinary twist drill with the cutting edge ground parallel to the axis similar to a straight fluted drill to make it suitable for drilling brass, etc.

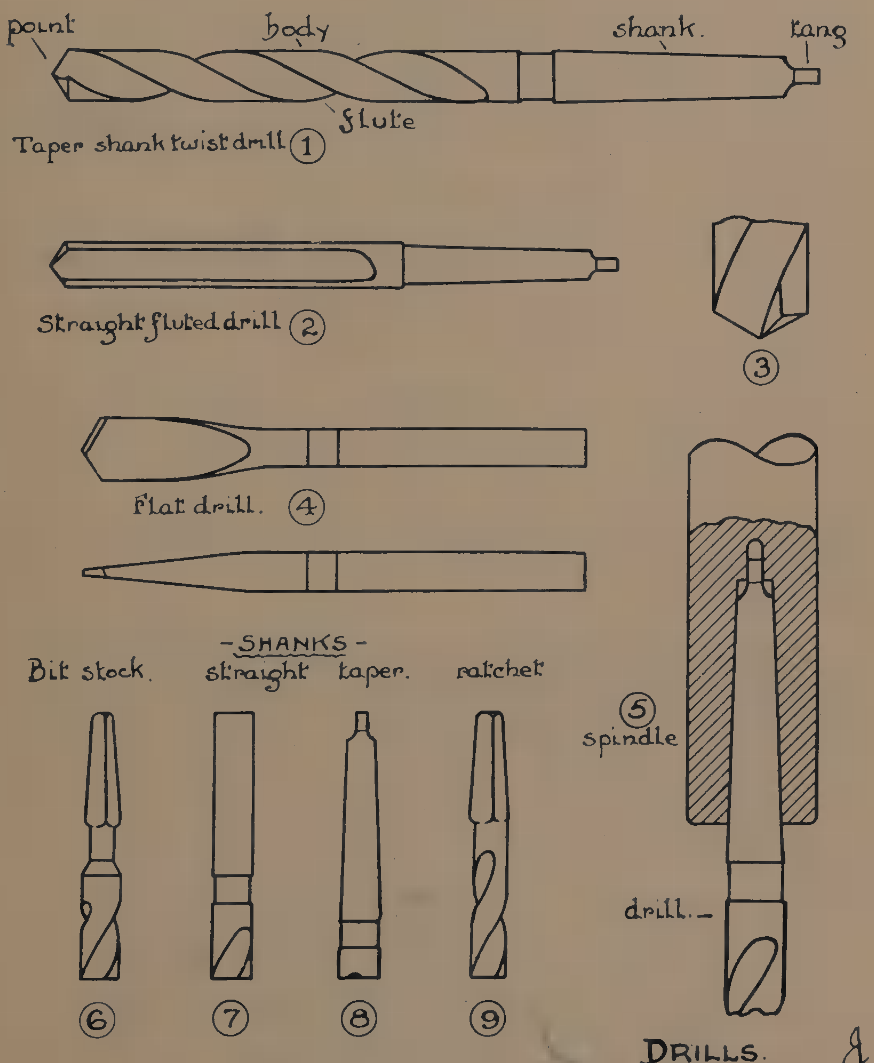
The flat drill, diagram (4), can readily be made from "drill rod" a carbon steel specially manufactured for drill making. In order that the flat drill may produce accurate work it is essential that the cutting end be symmetrical in every respect. The thinner the drill is at the point the better it will cut, providing it has sufficient metal to give it the required strength.

The fitting of the shank to the socket as shown in diagram (5) involves two distinct methods of driving the drill.

First, the taper of the drill gives increased friction with increased pressure on the drill. The taper "lines up" the drill axially true, provided it is clean with nothing in between the shank and the socket.

Second, the tang fitting into the corresponding slot in the socket provides a positive mechanical drive preventing any possibility of the drill slipping.

Drill shanks, diagrams (6), (7), (8), (9), show various forms of shanks used in drills. The commonest form of shank used is the morse taper shank shown in diagram (8) which has a taper of approximately $\frac{5}{8}''$ per foot, but the taper varies slightly in the different numbers which are from 1 to 6.


point
body
shank.
tang
flute
Taper shank twist drill (1)
Straight fluted drill (2)
(3)
Flat drill. (4)
-SHANKS-
Bit stock.
straight
taper.
ratchet
(5)
spindle
drill.
(6)
(7)
(8)
(9)
DRILLS.
J.

HOLDING WORK WHILE DRILLING.

If a piece of work to be drilled were held on the drill press table without any bolt or stop, the tendency would be for the drill to drive the piece of work around on the table, thus endangering the operators' hands, probably spoiling the work and breaking the drill. It is necessary therefore to prevent the work from turning with the drill, and also to hold it rigidly on the table with the centre of the hole opposite the centre of the drill. Sometimes it is convenient to hold work in the drill press vise. If so it is necessary to bolt the vise to the table and clamp the table in proper position at its centre and also correctly for height on the column of the drill press.

Stop plate. One of the simplest devices for preventing work from turning when being drilled is the stop plate. Some drill presses are provided with a stop plate; if not, a piece of metal can be bolted to the table as shown in diagram (1).

Bolt and strap. This is a very simple and common method of holding down work to the drill press. Note the correct methods of using the strap, in diagram (2). The nearer the bolt is to the work the greater will be the pressure applied.

Clamping work to an angle plate. It is convenient for some work with right angle faces to clamp it to an angle plate which in turn is bolted to the table. This brings the surface of the work to be drilled in a horizontal position as shown in diagram (3).

Drilling holes through a plate or flange. To drill through a plate it is necessary to raise the work from the face of the table by means of two parallels, then using two straps on each side to hold the work down rigidly as shown in diagram (4).

Drilling a round shaft. A round shaft is held best in a vee-block. A step block is used to hold the strap a convenient height and the shaft is bolted down securely. If the shaft is not too large it can be held securely in a vise which is bolted to the table.

Using a drilling jig (see page 40). A drilling jig has several advantages.

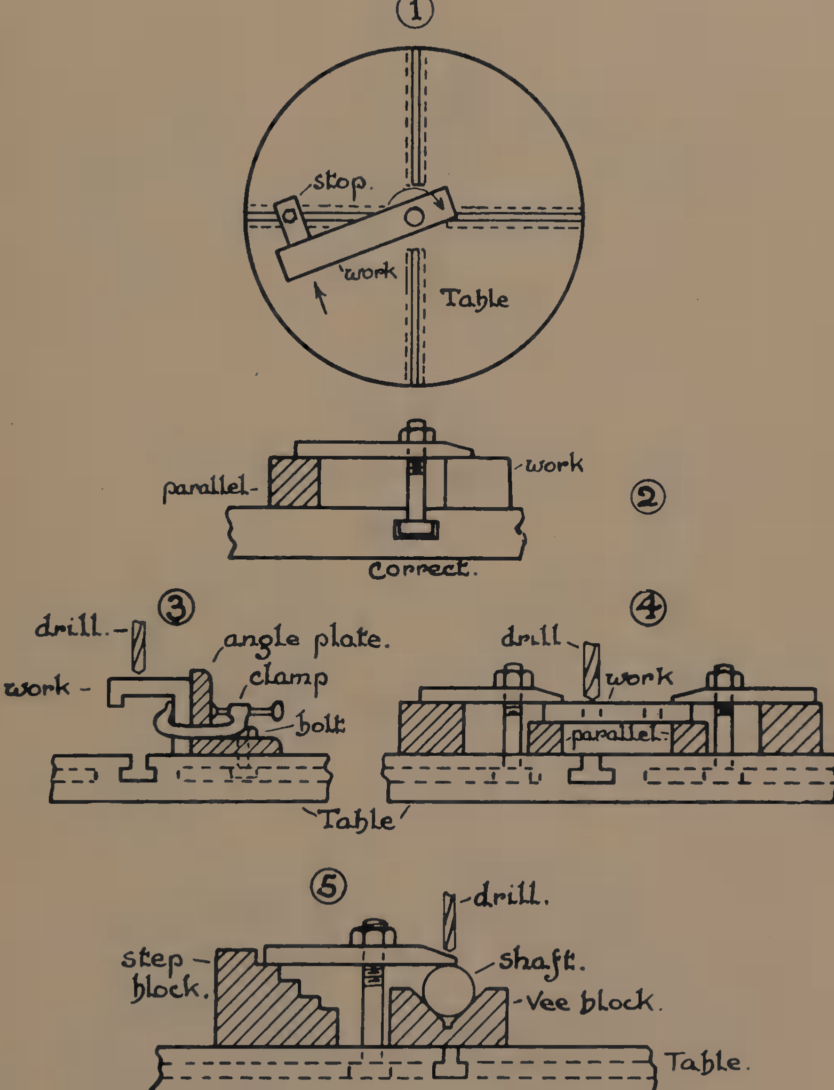
(1) It can be held down by straps or bolts as shown, or by special features designed in the jig itself of which there are many forms.

(2) It saves time in laying out holes.

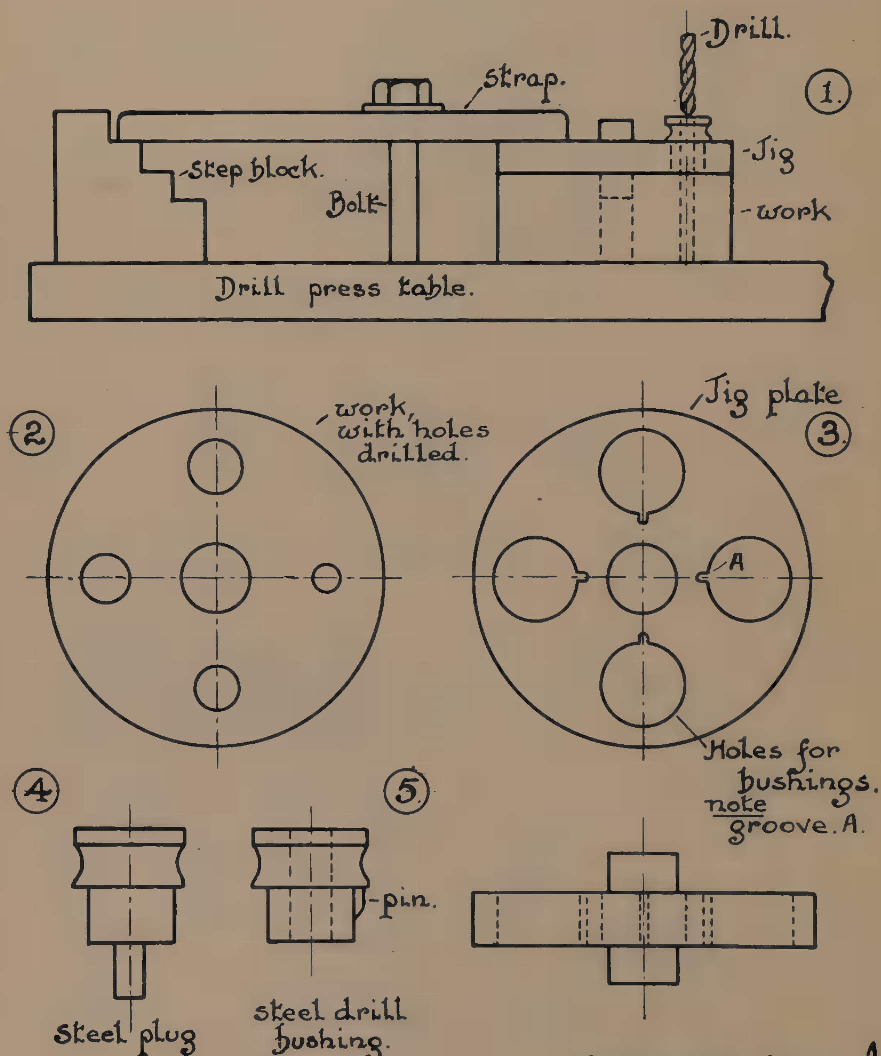
(3) It guarantees correct duplication of work.

(4) It provides a steady guide for the drill.

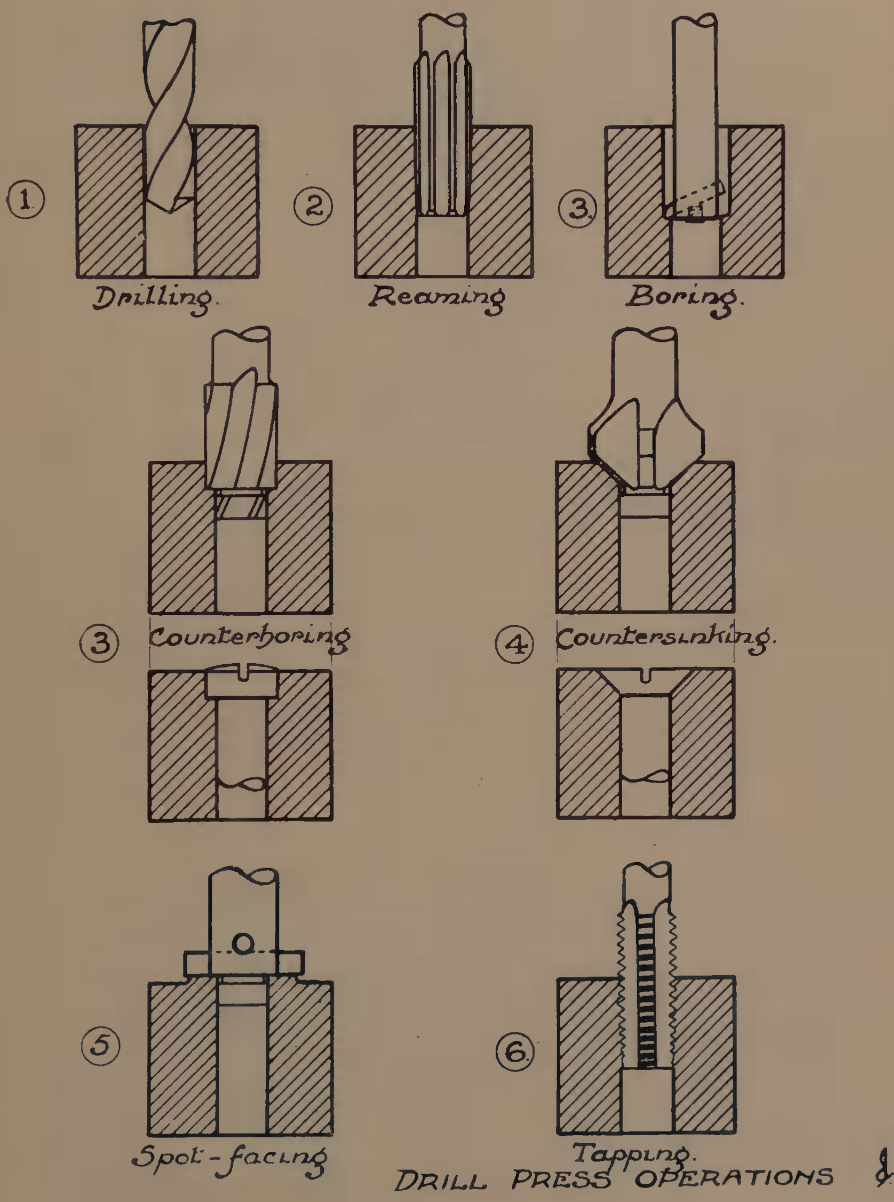
The simple plate jig illustrated on page (40) has a jig plate with holes to receive the hard steel drill bushings which are prevented from rotating with the drill by the pin on the bushing fitting into the groove A of the plate. The steel plug is placed in the first hole drilled and indexes the correct relative position of the remaining holes.



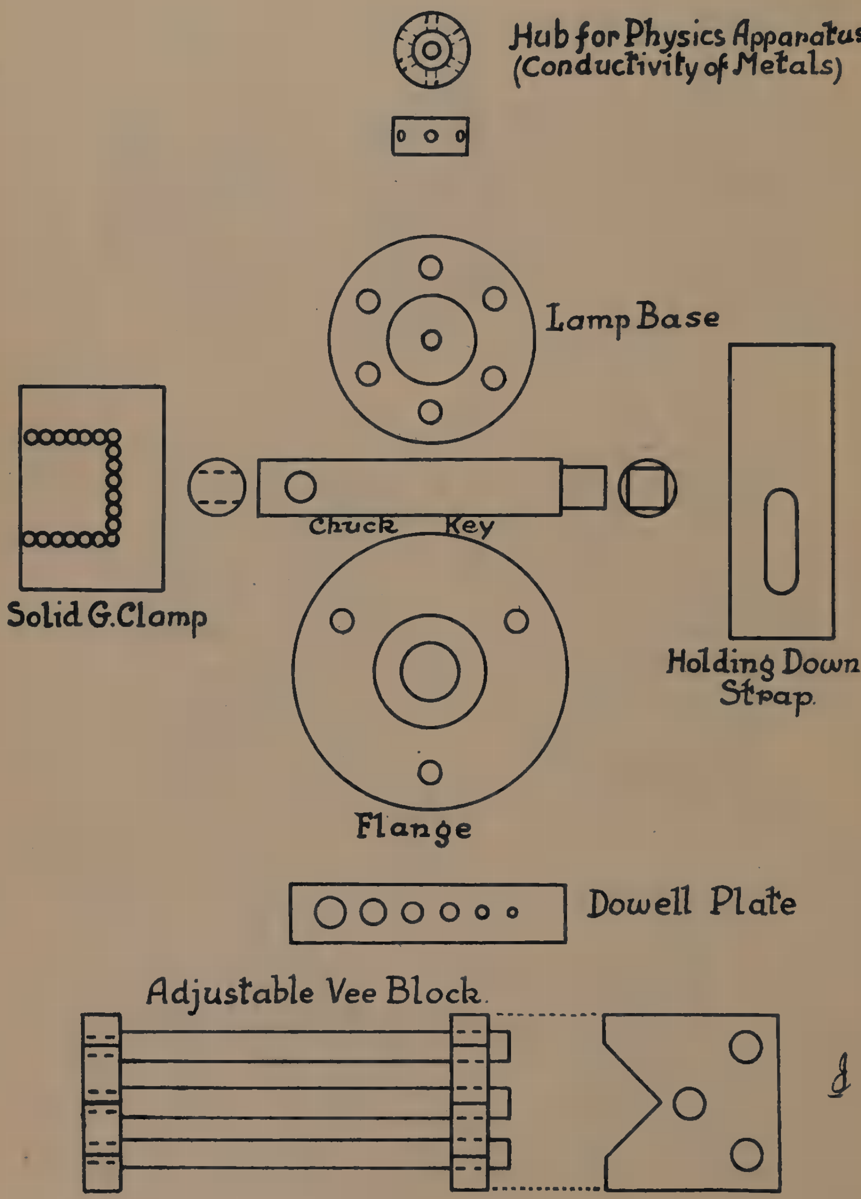
HOLDING DOWN WORK



DRILLING JIG 8


1
Drilling.
2
Reaming
3
Boring.
3
Counterboring
4
Countersinking.
5
Spot-facing
6
Tapping.
DRILL PRESS OPERATIONS

PROJECTS


Hub for Physics Apparatus
(Conductivity of Metals)
Lamp Base
Solid G. Clamp
Chuck Key
Holding Down
Strap.
Flange
Dowell Plate
Adjustable Vee Block.

QUESTIONS ON DRILING.

1. Trace the transmission of a drill press from the tight and loose pulleys to the rotating spindle.
2. How is a drill spindle raised or lowered?
3. How is the table of a drill press raised, lowered or fastened securely in one position?
4. How is the feed given to a drill press spindle?
5. Which drill would run fastest in drilling the same material, a small drill, or a large drill?
6. What are the different kinds of drills used?
7. How would you know when a drill is running too fast?
8. What are the ordinary drill chucks like those that are used for driving straight shank drills?
9. How are drill chucks fastened to a drill spindle?
10. What causes a drill to drill holes off the original position in which they are started?
11. How would you "draw" a drill hole that is off its true location?
12. Where should the table be placed in relation to the drill?
13. What is the danger in drilling thin metal? What precautions should be taken?
14. Why is a straight shank not used on large sized drills?
15. When is a sleeve or collet used?
16. When is a socket used?
17. How are taper shank drills removed from a sleeve or socket?
18. How would a hole be laid out to check up on the location after drilling?
19. When is a pilot hole first drilled in work?
20. What do you understand by "thinning the point" of a drill? When is this done?
21. Name the main parts of a taper shank drill.
22. When is a straight fluted drill used?
23. What are the common shanks of drills?
24. How does a taper drill fit into a drill spindle? What are the advantages of such a driving device?
25. What operations can be carried out on a drill press?
26. How can work be fastened to the table of a drill press?
27. What do you understand by a drilling jig? What are the advantages of using a jig?
28. What is likely to happen if work being drilled is not fastened securely to the table of the drill press?

LATHEWORK

THE LATHE.

The lathe is one of the most important of the tools used in the machine shop and although its construction is simple it is capable of turning out a great variety of work. The beginner would do well to learn the names and use of parts gradually. He should be quite sure he understands clearly the function of the parts of the machine and always remembers that a lathe is a precision tool and should be well taken care of. Oil the machine often and you will become acquainted and interested in each of the parts.

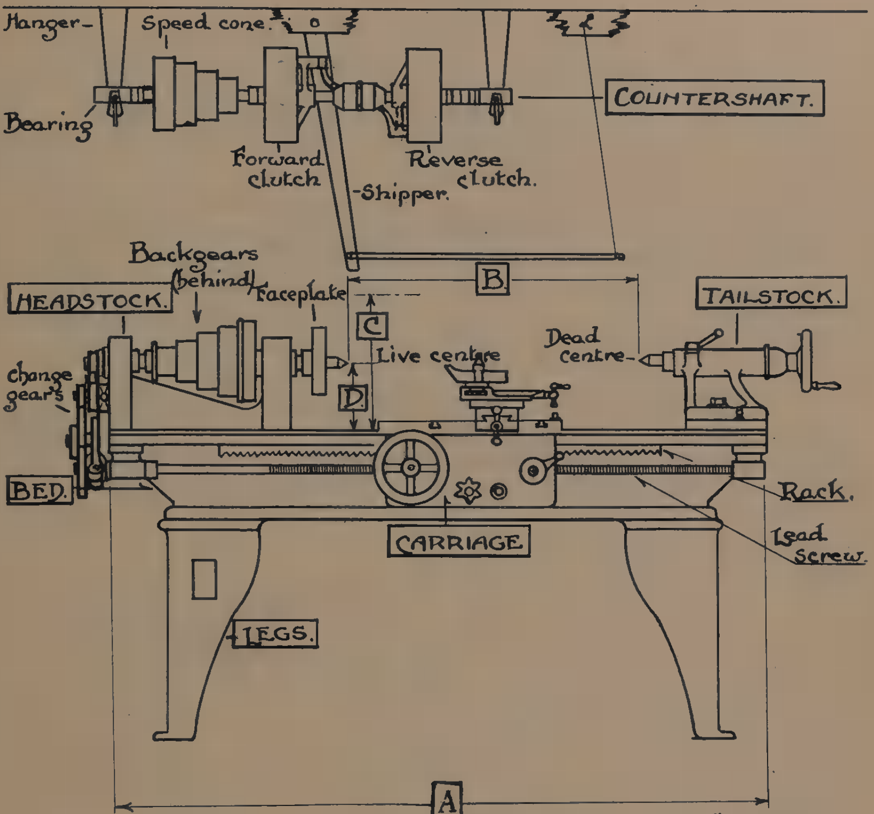
The main parts of the lathe are *the Bed* which is raised from the floor and supported by four legs to sufficient height for the convenience of the average man. The accurately machined surface of the bed carries the *Headstock, Carriage* and the *Tailstock;* while overhead the Countershaft is fastened to the ceiling to receive transmission by belt from the main shaft and transfer it by belt to the lathe.

The bed is made wide and deep to withstand heavy cuts and give to the whole machine rigidity and strength. The upper surface of the bed has "ways" or "Vees" which are accurately machined and scraped. The outside ways form a perfectly aligned track for the carriage to run on. The inside ways provide a permanent seat for the headstock and a perfectly aligned rest for the tailstock, which can be fastened in any position to suit the work.

The headstock casting is bolted firmly to the bed and carries the spindle made of crucible steel, which runs in two bronze bearings. At the end of the spindle a pinion is fastened which transfers rotation (through the reverse gears to the gears set up on the machine) to the lead screw or the feed rod. A hole extends through the spindle to allow small rods to pass through to be machined; and the front end of the spindle is tapered to receive the sleeve and "live centre". The nose of the spindle is threaded to receive the faceplate or the chuck, for driving or holding the work. The speed cone runs free on the spindle but in order to drive the spindle it must be fastened to the spindle gear by the locking pin. By unlocking the pin the spindle can be driven through the back gears.

The tailstock can be fastened on the bed by the bolt in any position required to suit the work. The tailstock spindle holds the dead centre, and the spindle is moved by turning the handwheel, and can be locked in position by the locking lever. The tailstock may be moved towards or away from the operator or "setover" as required for taper turning by means of adjusting screws on opposite sides of the tailstock. To remove the dead centre, turn the spindle back by means of the handwheel until the screw inside the spindle hits the end of the dead centre and ejects it.

The carriage has on its front side the *Apron* which carries the feed mechanisms controlling the long feed, cross feed, and the split nuts



SIZE of a LATHE = swing x length of bed e.g 16" x 8 ft.

A. Length of Bed B. Distance between centres.

C. Swing D. Radius = ½ swing.

Equipment provided.
Spare gears, large and small faceplates, center rest, follower rest, chuck back.

Equipment to be provided extra
Universal 3 jaw chuck
Independent 4 " "
Drill chuck
Tools

which engage with the lead screw used only for screwcutting. The top of the carriage consists of the *Saddle*, which carries the cross slide, compound slide rest and tool post.

Size of a lathe is determined by the amount of swing and the length of the bed, such as 16″ x 8 ft., that is 16″ swing and 8 ft. length of bed.

Types of lathes. Engine lathes, Turret lathes, Bench lathes, Jewellers lathes, Pulley lathes, Axle lathes, Wheel lathes.

LATHE TOOLS.

It is very necessary for the beginner to have at least an elementary knowledge of the different tools which may be used on the lathe. Tools required for use on the lathe must usually be obtained from the tool room and the proper selection of the tool is very essential for doing work in the best possible manner.

Forged tools as shown in diagram (1) may be made of Carbon Steel or High Speed Steel, and are forged out to shape from a suitable-sized bar of steel, then hardened, tempered and ground. After many grindings they are again forged and tempered until the steel is too short for convenient use. The forged tool is a very rigid tool, being made of one piece of metal but they are rapidly being superseded for general use by the tool holder and tool bit or blade, because they are more economical.

Tool holders and tool bits. The tool-holder is made of a tough steel. It is provided with a square slot into which the high speed steel tool bit is placed as shown in diagrams (2) and (3). The slot is inclined to give to the tool a suitable inclination to the work, thus saving the time and material which would be lost if front rake had to be ground on the tool bit.

The set screw type of tool-holder, diagram (2), is a simple tool to set up, the screw is carefully heat treated and hardened to give it durability.

Cam type of tool-holder, shown in diagram (3) is rapid and positive, the greater the pressure on the tool the tighter it locks, and offers full freedom for operation. The hexagonal head of the cam is on the opposite side from the cutting face of the tool.

Straight tool, diagram (4), is used for the turning of plain work as shown.

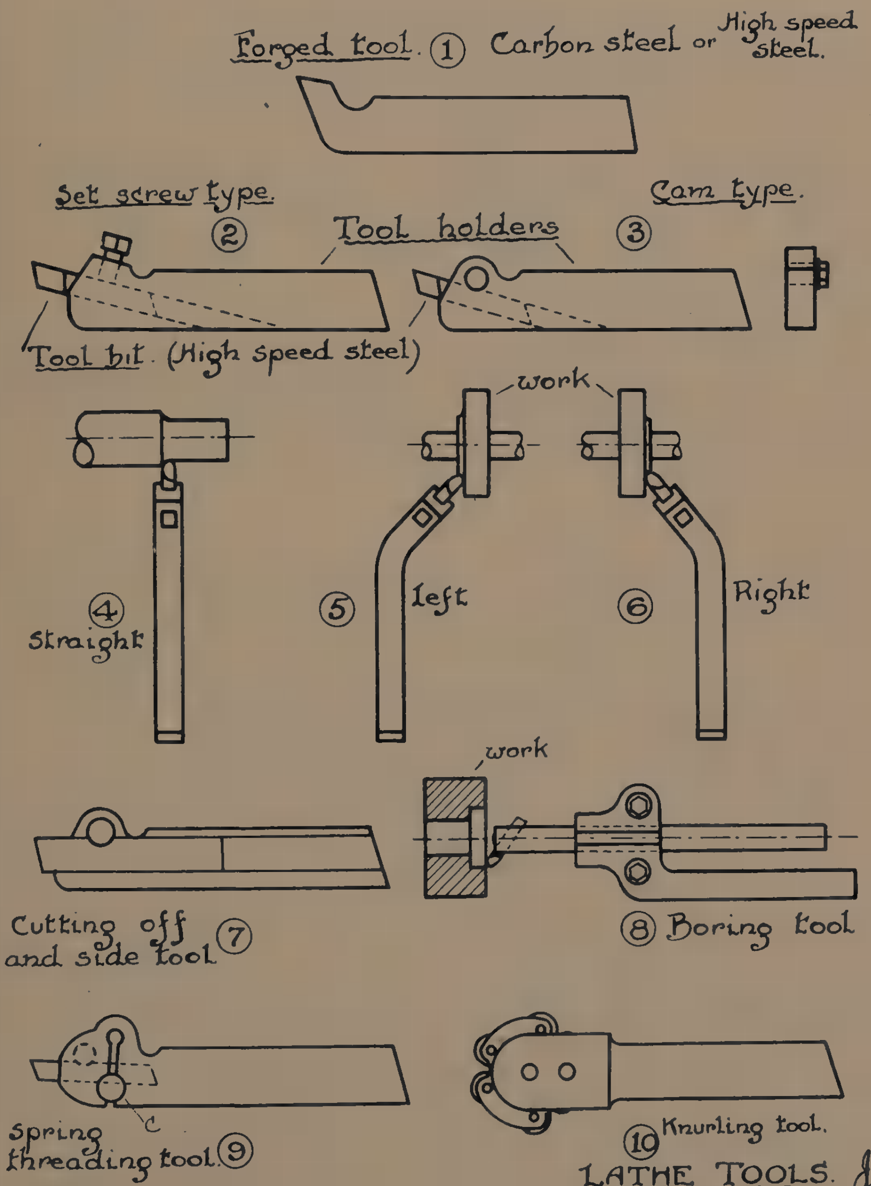
Bent tools, as shown in diagrams (5) and (6), are used as illustrated and are very suitable tools for working near to shoulders, flanges, or work held in chucks.

The cutting off or paring tool, diagram (7), has a blade which can be adjusted in or out. This tool can hold a thin blade for cutting off and a thicker blade for side cutting.

The Boring tool shown in diagram (8) is made to hold various sizes of boring bars. The two cap screws which hold the bar rigidly to the holder can be loosened to allow the bar to be turned to elevate or lower the tool.

The spring threading tool, (diagram 9). This is a special tool made for screw cutting and is designed on the "goose neck" principle of spring tools. For light work the cam (c) may be removed allowing full freedom for the tool to spring and produce a smooth thread. For heavy cuts the cam may be tightened as required.

The knurling tool, (diagram 10), carries three pairs of knurls fine, medium and coarse, each wheel cuts a helical groove in the metal and as the helical grooves are opposite a diamond is formed.


Forged tool. 1 Carbon steel or High speed steel.
Set screw type.
Cam type.
2
Tool holders
3
Tool bit. (High speed steel)
work
4 Straight
5
left
6
Right
work
Cutting off and side tool 7
8 Boring tool
Spring threading tool 9
c
10 Knurling tool.
LATHE TOOLS.

TOOL POSITION.

The position of the tool in relation to the work being turned is a very important consideration and beginners will do well to study the effect of the various positions of the tool. Much work is spoilt and in many cases the machine is damaged by lack of foresight on the part of careless operators.

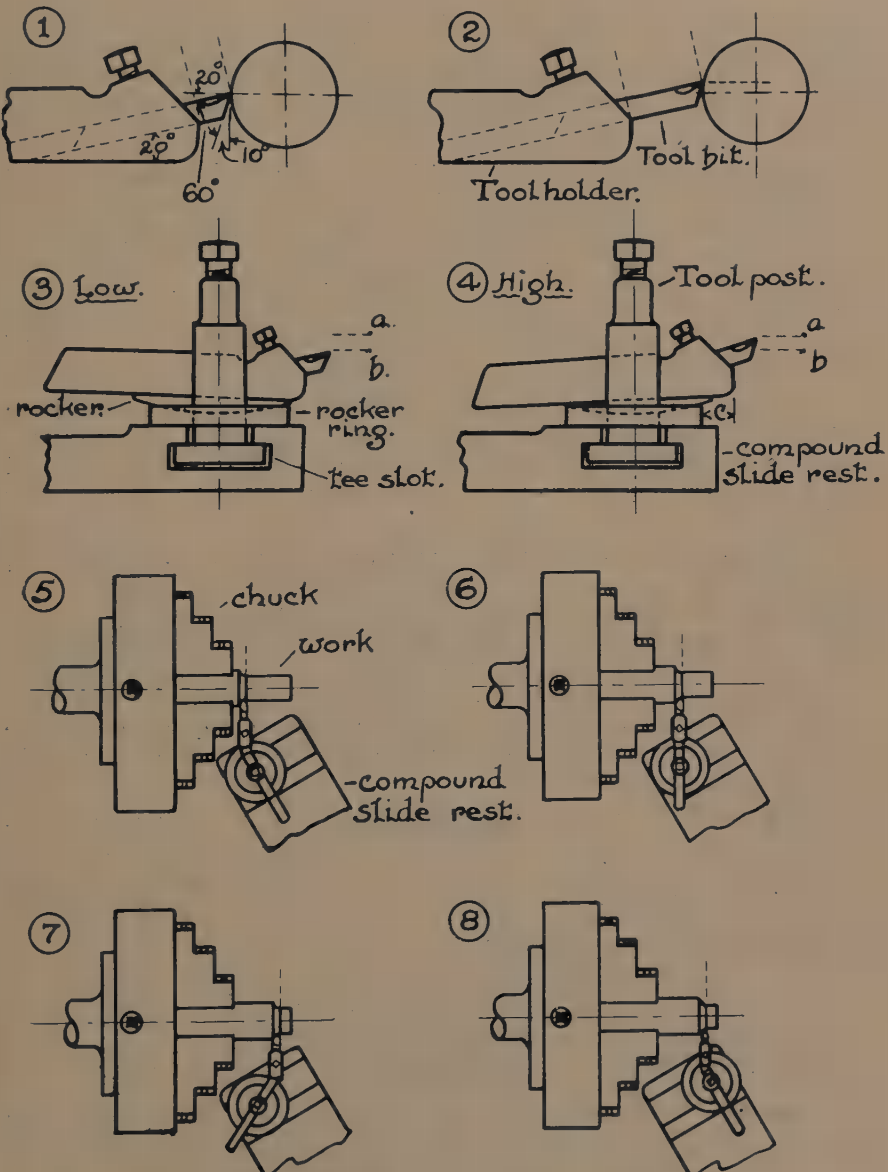
Diagrams (1) and (2) show how it is possible to obtain elevation of the tool bit by moving it outwards from the inclined slot of the tool-holder. This inclination is given to the tool to give it front rake without having to grind it on the tool-bit. Diagram (2) shows an extreme position of the tool-bit which, of course, would weaken it and probably be the cause of breaking the tool bit under the pressure of the chip.

To elevate the tool. The usual method to elevate or lower the tool is to swivel the toolholder up or down on the rocker in the rocker ring of the toolpost. Diagram (3) shows the lowered position of the tool and Diagram (4) the elevated position, showing a difference at a.b. in the elevation.

The rigidity of the tool. The tool should not project any further from the toolpost than is absolutely necessary, because the further it protrudes the greater will be the strain on the machine due to the increased moment acting from the last point of support as shown at (c). This is often sufficient to push the tool down changing its setting and sometimes causing it to dig into the work.

The position of the tool in relation to the machine. The position of the compound slide rest, the location of the tool post in the tee slots provided for it, and the type of tool holder used, must all be considered in the setting of the tool. If work is being turned in the chuck as shown in diagrams (5) to (7) it can be seen that when the tool post is in a location as near the chuck as possible the type of tool used will influence the conditions of the work. It is quite a common thing to see the compound slide or cross slide of a lathe damaged by some careless operator running it into the rotating chuck, because the tool is not set in the proper position. Diagram (5) shows a left-side toolholder being used because in this position its bent shape allows it to work quite near to the chuck without the chuck striking the corner of the compound rest. Diagram (6) shows that the straight tool cannot work as near to the chuck as the tool in diagram (5) and the tool in diagram (7) is much worse. Diagram (8) shows the best tool for working close to the chuck, but it is set too far away from the chuck due to the location of the tool-post in the tee slot, so that in this position the chuck will damage the corner of the compound slide rest.

It is therefore advisable for the beginner to select the best tool for the work he has to do and always to place it in such a position, so that it will be rigid and will not cause any damage to the work or the machine.



TOOL POSITION J.

TOOL POSITION AND TOOL GRINDING.

The first lesson on tool position for the lathe (Page 48) dealt with the position of the toolholder and the tool from an adjustment standpoint. This lesson deals with the influence of the tool position in producing a smooth clean surface on the work, both on the lathe and the planer.

Diagram (1) shows a planer tool in operation projecting beyond its last point of support A of the machine. If it were a thin strip of metal projecting beyond the point A as soon as the extremity came in contact with the resistance offered by the work, it would spring away from it, pivoting about the last point of support or fulcrum A. The planer tool shown under chip pressure tends to spring slightly as shown by the dotted line, digging into the work and sometimes producing a rough or "chattered" surface.

Diagram (2) shows a "goose neck" or spring tool in operation for finishing. When sufficient pressure acts at the point of the tool it springs away from the work slightly, as shown in direction of the dotted line and produces a smooth finish. This same action occurs in a lathe spring tool.

Diagram (3) shows a lathe tool in the best position for cutting with the front edge tangent to the surface of the finished work. In this position it carries the minimum load and does efficient cutting. In general, tools should be set at 5° above the centre as shown in diagrams (3) and (4) which is the best position (except for threading tools which cut better on centre). Due to the variation in stock diameters, the height of the tool above the centre will vary, being higher for larger diameter stock as in diagram (3), and lower for smaller diameter stock as in diagram (4).

Diagram (5). The straight grinding shown by the straight line only produces the same front rake angle at the point as the curved one yet it removes more metal from the tool, taking a longer time to grind and producing a weaker tool.

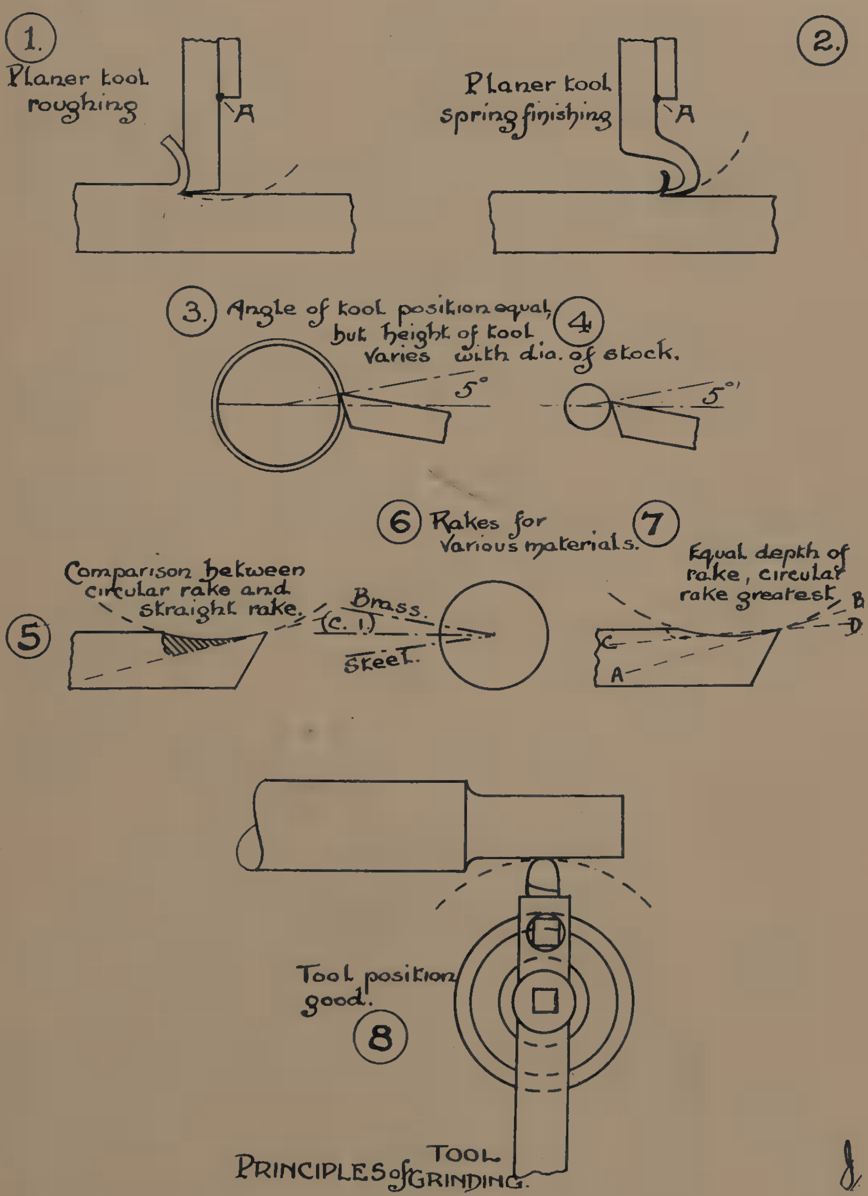
Diagram (6) gives a general idea of front rake angles.

(1) *The brass tool* having a negative front rake.
(2) *The cast iron* tool, having no front rake.
(3) *The steel tool* having a distinct front rake.

Note: See table on tool grinding for materials (Page 159).

Diagram (7) shows a comparison between curved and straight front rakes for the same depth. The curved rake has a front rake angle equal to A B, while the straight rake has a lesser angle equal to C D.

Diagram (8) shows the best position for the tool. It projects only a small distance from the tool post, giving it rigidity and under chip pressure it would tend to move away from the work as shown by the dotted line thus producing smooth work.


1.
Planer tool roughing
A
2.
Planer tool spring finishing
A
3.
Angle of tool position equal, but height of tool varies with dia. of stock.
4
5°
5°
6
Rakes for various materials.
7
Comparison between circular rake and straight rake.
5
Brass.
(C. I.)
Steel.
Equal depth of rake, circular rake greatest.
B
D
C
A
Tool position good.
8
PRINCIPLES of TOOL GRINDING.

CHUCKS AND FACEPLATES.

Work on the lathe may be carried out in three different ways; work on the lathe centres, chucking work and face plate work. Various operations can be undertaken in each of the "set ups".

The universal chuck, diagram (1), so called because the jaws move together. It is provided with a chuck plate, which is threaded to fit on to the threads on the lathe spindle. This chuck is suitable for holding work that is round and is the simplest form of chuck for a beginner to work with.

The independent chuck, diagram (2), is used chiefly for work that is not perfectly round or work of various shapes similar to that shown in the diagram. If a hole has to be bored in a position off centre as shown, each jaw is adjusted separately to hold the work in the location desired. A beginner will find difficulty at first in using this chuck. If a centre dot is placed on the work and the dead centre held against it the setting up of the work will be simplified.

Combination chuck. This chuck can be used either as a "Universal chuck" or an "Independent chuck". It contains the spiral or scroll for controlling the movement of the jaws and the screw by which each jaw is adjusted separately.

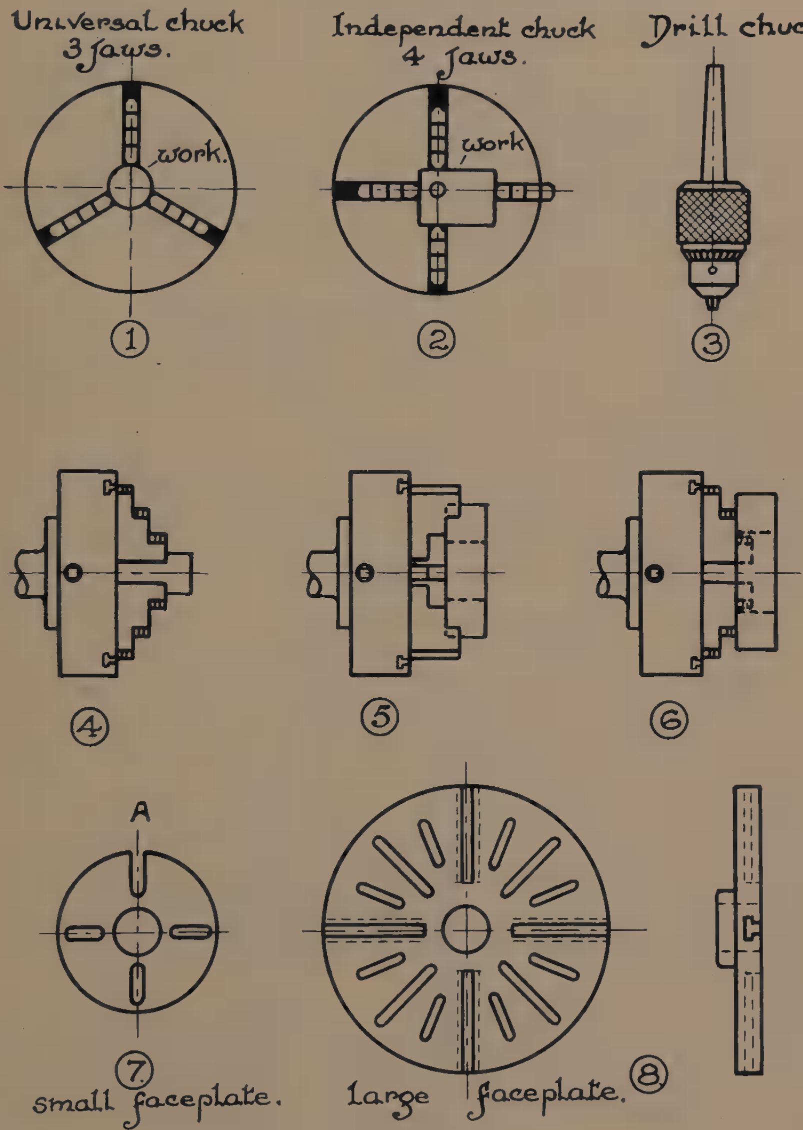
Spring chucks or "Draw in Chucks" are often used for small round work. The adapter fits the taper hole in the main spindle and the chuck fits into the adapter, being drawn in by operating a hand wheel at the opposite end of the spindle.

The drill chuck, diagram (3), is provided with a taper shank arbor which fits into the taper hole in the main spindle or the tailstock spindle. If the spindle has a larger taper size it is made to fit by the use of a suitable sized "sleeve".

Use of chuck jaws. Some chucks have reversible jaws, others have two sets of jaws. Diagrams (4) and (5) show work being held on the outside and Diagram (6) shows the work being held inside with an outward pressure. The work shown in diagrams (5) and (6) would be bored first and faced on one side, then it would be held as in diagram (6) and faced on the other side and the outside turned.

Use of faceplates. The small faceplate shown in diagram (7) is the one usually used for driving the lathe dog when the work is rotating between centres. The slot marked (A) is the best one to use to drive the lathe dog because if the tail of the dog pressed against the top of the closed slots the work would be strained.

The large faceplate. Diagram (8). Some work cannot be machined on centres or held in a chuck, but it can be bolted to a faceplate to be machined. Various clamps, angles, plates and weights for counterbalancing the work being used.



CHUCKS and FACEPLATES.

THE USE OF CALIPERS.

The majority of ordinary work on the lathe is measured with calipers, and the successful use of the caliper can only be attained by practice. The caliper could be used to obtain many variations of size and it is only by developing a sense of "feel" that any guarantee of size can be obtained. Many beginners force the caliper over work making believe that it is the size to which the calipers are set, but the calipers just spring over. It is therefore necessary to use a very delicate touch to use calipers successfully. Never caliper work while it is running, it is very rarely accurate and the calipers may be caught by the work and broken.

Adjusting calipers to size. Diagram (1) shows the method of setting outside calipers to size after approximate setting by hand. The calipers are tapped gently on a block closing them slightly; if too close they are not opened by hand, but by tapping on the end as shown in diagram (2) they will open slightly.

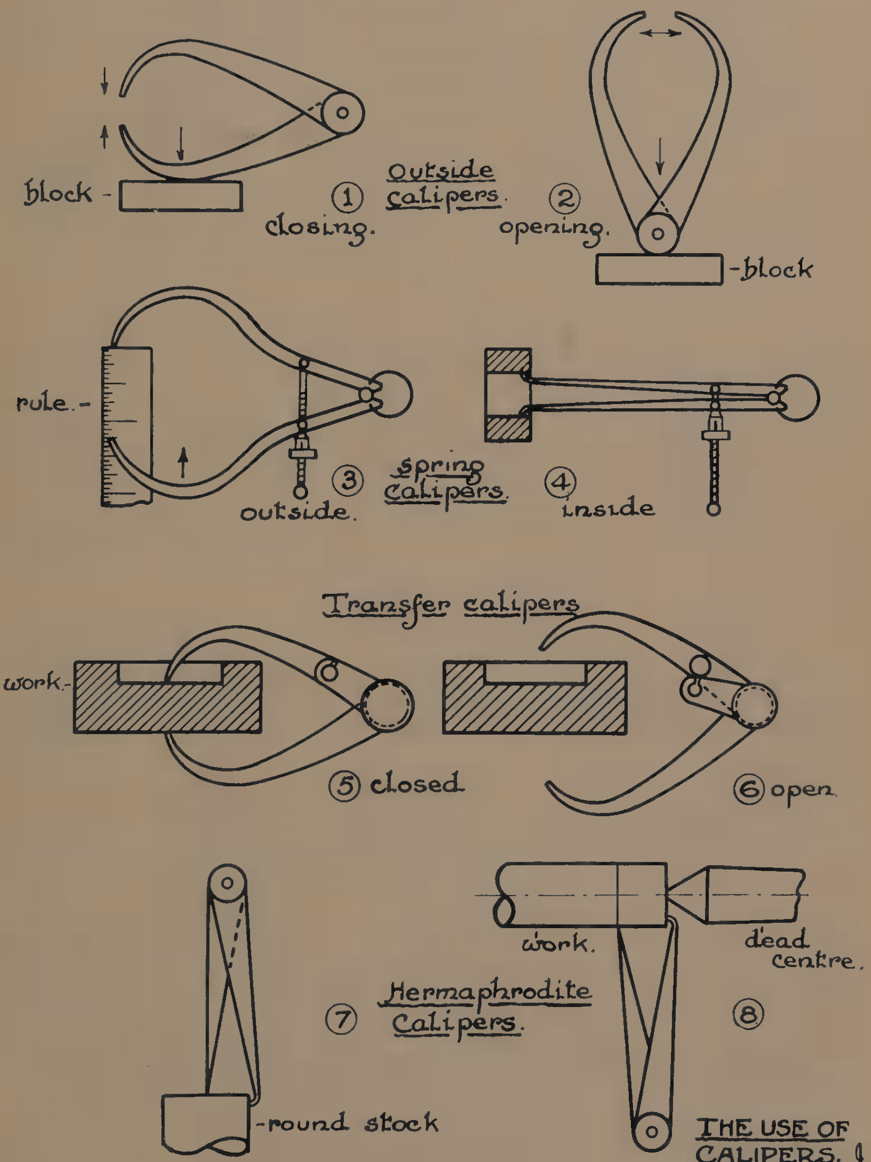
Spring calipers are very sensitive calipers to adjust and use. Diagram (3) shows the method of setting the calipers to size. When the adjusting screw is tightened one leg is pulled snug against the end of the ruler while the other moves down to the size.

Inside calipers. Unless the calipers are held in the position shown in diagram (4) a true reading cannot be obtained. Both outside and inside calipers must always be held in such a position that the measurement obtained is at right angles to the axis of the work.

Transfer calipers with lock joints as shown in diagrams (5) and (6) are very convenient for measuring a piece of work as shown where ordinary calipers could not be used without changing the setting. These calipers may be removed from the work and replaced without losing the size calipered. This is done by loosening the nut binding one arm to the auxiliary leaf and swinging it out or in (while the joint is locked) to clear the obstruction, then moving it back against a stop where it will show the exact size measured.

Hermaphrodite calipers are used as in diagram (7) to locate the centre of stock. The calipers are adjusted so that when the bent leg is against the side of the stock the straight leg is approximately on centre; four lines are scribed on the end of the work from the four quadrants of the circular stock. In the small area so enclosed it is an easy matter to place a centre punch and mark the centre of the stock.

Diagram (8) shows the Hermaphrodite Calipers being used to mark a distance from the end of stock, while the work is in the lathe. The work should be covered with copper sulphate and while the bent leg is against the end of the stock the work is rotated slowly by hand while the straight leg scribes a line around the stock.


block
① Outside calipers. ②
closing.
opening.
block
rule.
③ spring calipers. ④
outside.
inside
Transfer calipers
work.
⑤ closed
⑥ open
work.
dead centre.
⑦ Hermaphrodite Calipers.
⑧
round stock
THE USE OF CALIPERS.

SQUARING STOCK FOR LATHE.

Squaring stock for lathe. Diagram (1) shows stock mounted on centres with a very irregular end just as it comes from the mill. If this were allowed to rotate on centres it would cause unequal wear on the centres and would wear the centre holes out of round.

Diagram (2) shows stock that has been sawn out of square in the power hacksaw. If this were rotated between centres a similar result to that explained in Diagram (1) would be produced. Therefore, it is necessary to have the ends of the work perfectly square before rotating between centres for any length of time.

Diagram (3) shows a squaring tool incorrectly placed. Although the cross feed screw is operated to square the work the tool position will leave the work out of square owing to its inclination.

Diagram (4) shows a squaring tool in the proper position for squaring with its cutting face inclined at 5° under cutting. To rough square the tool is operated towards the head stock in a series of broad steps. This leaves the work serrated and it is necessary to follow by a finishing operation.

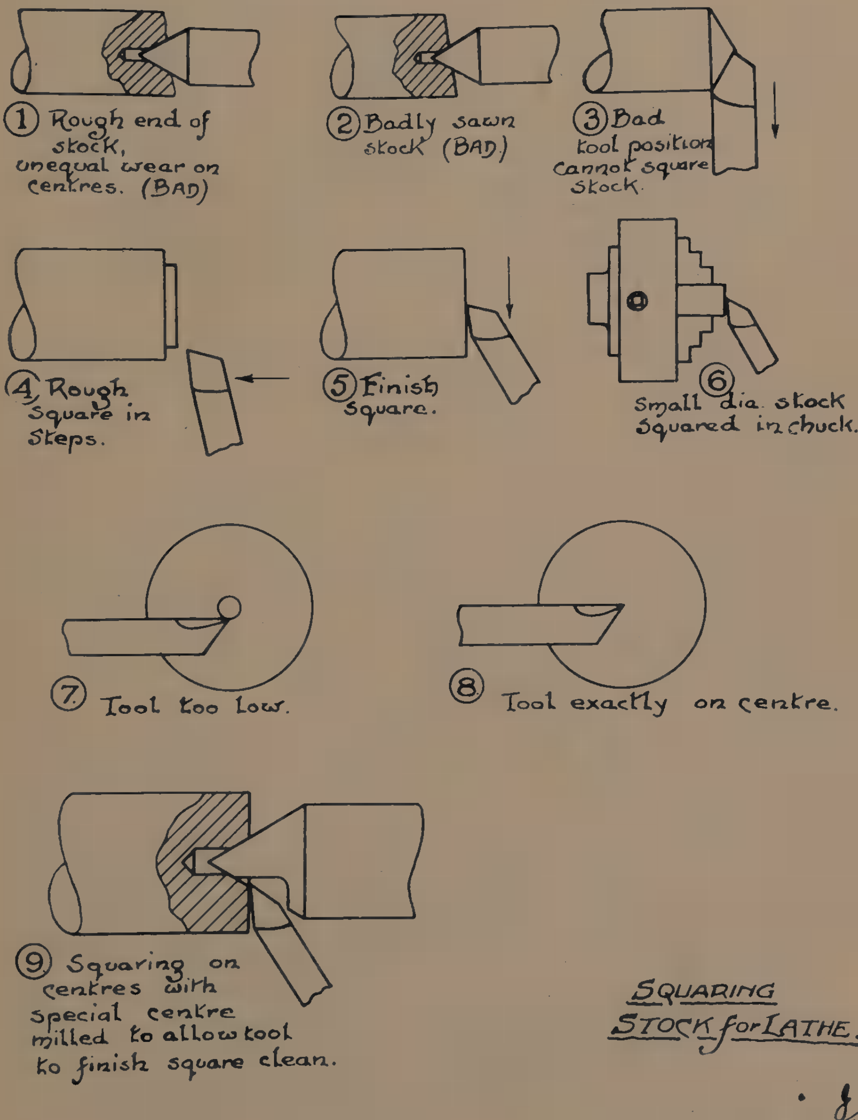
Diagram (5) shows the squaring tool set for the finish squaring operation. It is operated from the centre of stock towards the outside. Unless the carriage of the lathe is rightly locked on the bed the face of the work would not necessarily be square.

Diagram (6). If the stock is small in diameter and will pass through the lathe spindle or if it is short in length it is possible to square it while being held in the chuck, although this method would not produce faces as square as if rotated on the centres of the stock.

Diagram (7) shows that if the tool is set too low it is impossible to completely square the stock, as the tool passes under a small projection of metal.

Diagram (8) shows a clean squared face produced by setting the squaring tool exactly on centre.

Diagram (9). It is sometimes difficult to finish square the stock to the centre hole while rotating on centres because the point of the tool hits against the dead centre and leaves a slight burr near the centre hole. If a special milled dead centre is used as shown in Diagram (9) the tool can pass in clean to the centre hole leaving the work smooth throughout.


① Rough end of stock, unequal wear on centres. (BAD)
② Badly sawn stock (BAD)
③ Bad tool position cannot square stock.
④ Rough square in steps.
⑤ Finish square.
⑥ Small dia. stock squared in chuck.
⑦ Tool too low.
⑧ Tool exactly on centre.
⑨ Squaring on centres with special centre milled to allow tool to finish square clean.
SQUARING STOCK for LATHE.

FINDING THE CENTRE OF STOCK.

Importance of locating centre accurately. If the location marked is not exactly in the centre of the stock it will mean that the outside of the stock will rotate eccentrically, the tool taking a small chip on one side, and a thicker chip on the other. This condition practically gives a rotating wedge, and, due to its varying pressure on the tool point, will cause the centre hole to wear irregularly, and tend to make the work out of round. It is also necessary to remove at least $1/32''$ all around a bar of tool steel, owing to the steel on the outside being decarbonized while rolling at the mill. If this skin were not removed this portion would not properly harden when required in the finished work.

A similar condition has to be met with in cast iron. All of the skin which is very hard should be removed. Therefore, it is important that the centre be located as nearly as possible to the true centre to remove the skin evenly.

The centering machine is provided in most well equipped shops. It holds the work central with a drill spindle so that the locating and drilling are undertaken in one operation.

Method of locating the centre of stock. Diagram (1). The Hermaphrodite Caliper, sometimes called "Morphy", consists of a bent caliper leg with a straight divider leg. To use this, first mark the surface of the end of the stock with chalk, or, if the metal is smooth and bright, coat it with copper sulphate. Set the calipers to a distance approximately equal to the radius of the stock with the bent caliper leg against the side and scribe 4 arcs as shown in diagram (1).

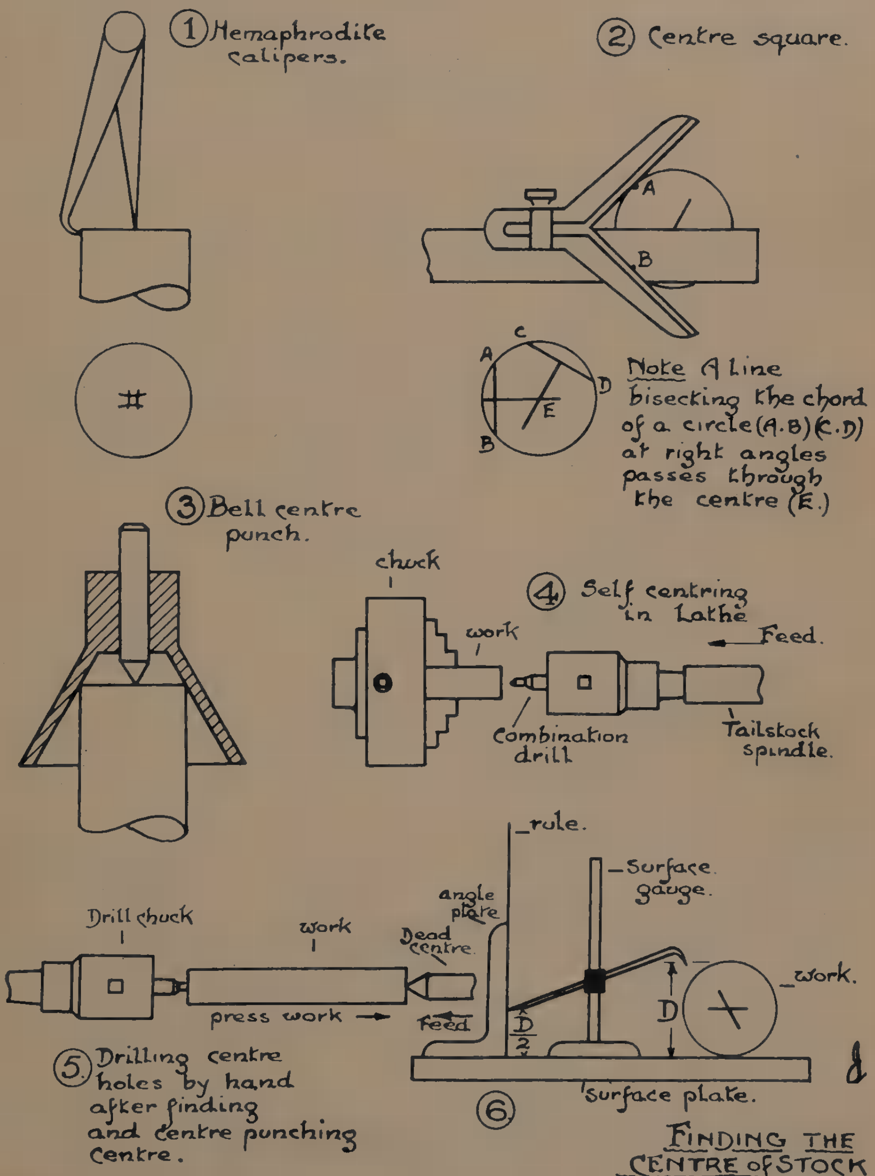
Diagram (2)—*The Centre Square,* when placed in contact with a cylinder, as shown, gives 2 points of contact (a) and (b). If these points were joined (a b) would be the chord of a circle. If a chord of a circle is bisected at right angles, as shown, the lines would pass through the centre of the circle, so that two intersecting lines locate the centre.

Diagram (3)—*The Bell Centre Punch* may be used for stock within its capacity. It locates and centre punches stock in one operation.

Diagram (4)—*Centering in Lathe.* This method is suitable for small diameter stock that can be placed in the chuck. It locates, centres and drills the centre hole in one operation. (*Note*: Be quite sure the tailstock of the lathe is not "setover.")

Diagram (5)—*Centering in Lathe by hand method.* First locate the centre of stock and centre punch deeply then press the work against the dead centre while the tailstock pushes the work against the rotating drill in the drill chuck fitted direct into the lathe spindle. A dog may be used on work to prevent rotation.

Diagram (6)—*Surface Gauge Method.* The centre of stock may be found on the surface plate by using the surface gauge, as shown. Set the height of the scriber point one-half the measured diameter of stock, then mark the stock in two positions. The intersection of the scribed lines will be the centre of the stock.


1 Hemaphrodite calipers.
2 Centre square.
A
B
C
D
E
Note A line bisecting the chord of a circle (A.B) (C.D) at right angles passes through the centre (E.)
3 Bell centre punch.
chuck
4 Self centring in Lathe
work
Feed.
Combination drill
Tailstock spindle.
rule.
Surface gauge.
angle plate
Drill chuck
work
Dead centre.
press work
feed
work.
D
D/2
5 Drilling centre holes by hand after finding and centre punching centre.
6
surface plate.
FINDING THE CENTRE of STOCK

MOUNTING WORK ON CENTRES.

Diagram (1) shows work mounted on centres which are dotted to locate the centres, but without centre holes. If the work were rotated in this condition against a stationary tool, it would immediately be torn from between centres, damaging the centres or scoring the end of the work.

Diagram (2) shows work with a hole drilled in the end to prevent it from being forced from centres under tool pressure. If the work were allowed to revolve, the dead centre would be worn, as shown, with the sharp edge of the drilled hole.

Diagram (3) shows that if the holes were made conical to fit the centre the point of the centre would have too much strain and would wear off. There would be no provision for lubrication and the particles of metal worn off, would work their way out of the hole, eventually wearing off the whole of the point, as shown in diagram (6) below.

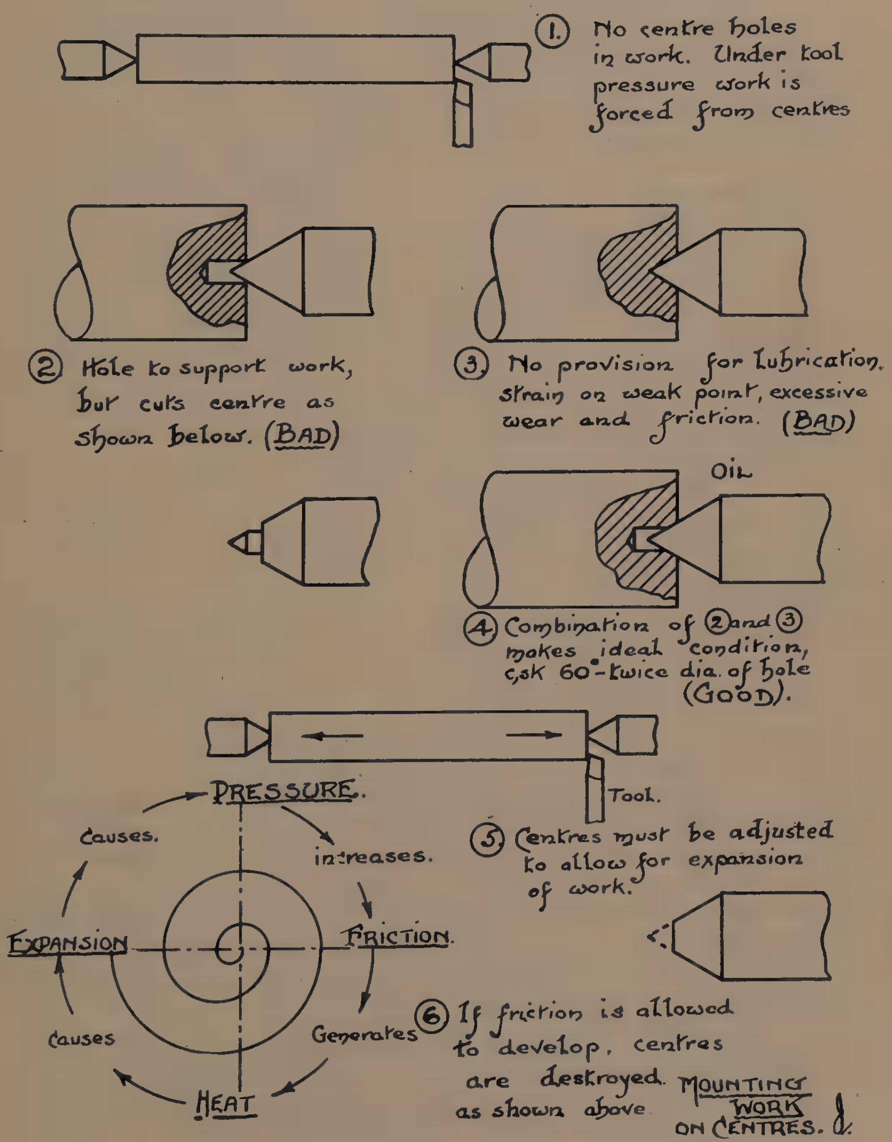
Diagram (4) shows that by combining (2) and (3) an ideal condition is obtained. There is no strain on the weak centre point, the greater diameter carrying the load, and there is sufficient bearing surface provided to prevent cutting the dead centre. A space is provided in the hole for the oil to reduce the friction.

Diagram (5) shows that metal being turned will naturally expand, due to the heat generated by the cutting action of the tool, and pressure will occur (in the direction of the arrows) on the centres. Therefore, the dead centre must be adjusted for pressure on the work from time to time. The centre should just bear on the work slightly. The slackness between centres need only be taken up. If care is not taken in this adjustment, friction will develop rapidly, and the centre will be ruined.

Diagram (6) expresses, by means of a spiral, the effect of friction when allowed to develop. Friction generates heat, and heat causes expansion. Expansion of metal between the fixed centres of the lathe would cause pressure, and increased pressure causes increased friction, so that if friction is allowed to develop, it eventually destroys the centres and the work drops from between them.

Note—Beginners should give special attention to this important lesson. Friction enters largely into the mechanical field and is the cause of great financial loss when the laws of friction are not obeyed.

It is well to observe the design of bearings, etc., also the provisions for lubrication which help to prevent friction, thus keeping down loss of power and increasing efficiency.



(1.) No centre holes in work. Under tool pressure work is forced from centres
(2) Hole to support work, but cuts centre as shown below. (BAD)
(3) No provision for lubrication. Strain on weak point, excessive wear and friction. (BAD)
OIL
(4) Combination of (2) and (3) makes ideal condition, c,sk 60°-twice dia. of hole (GOOD).
Tool.
(5) Centres must be adjusted to allow for expansion of work.
PRESSURE.
increases.
FRICTION.
Generates
HEAT
causes
EXPANSION
causes.
(6) If friction is allowed to develop, centres are destroyed as shown above
MOUNTING WORK ON CENTRES.

TURNING TO A SHOULDER.

There are various methods of turning to a shoulder, depending largely upon whether the work is held in a clutch or being turned between centres. The finishing of the corner at the shoulder also may vary, depending upon whether the work is to be threaded to the shoulder or left plain.

Marking the work. The first thing to do is to mark a line at the required distance from the end of the work. Chalk the spot where the line is intended to be marked, or if the metal is bright use Copper Sulphate Solution. The line may be marked with a Hermaphrodite caliper or a rule and scriber.

Diagram (1) shows a method of squaring to the shoulder with a parting tool. The tool is set a slight distance from the line on the waste side, and fed into the work as shown leaving the diameter a little larger than the finished size. The remainder can be finished with a tool as shown in diagram (1) B.

Diagram (2) shows a method of squaring from the end of the stock with a side tool which may be an ordinary high speed steel cutter (a) or a special side tool cutter blade (b). Rough turn as shown, then finish with a light cut to the dotted line.

Diagrams (3) and (4) show a general method of squaring to a shoulder. First by roughing, as shown, not quite to the line and second by using a special finishing tool A.

The finishing tool shown at A produces a nice finish on the work. It is ground with just sufficient clearance on front and side, and the corner is a right angle $1/16''$ back each way, while the point is slightly rounded with an oilstone.

Diagram (5) shows that in turning a piece of work all over, if a shoulder has to be formed it is best usually to turn to the shoulder first; and if driving work between centres put the lathe dog on the reduced portion, afterwards cutting through to the shoulder clearance.

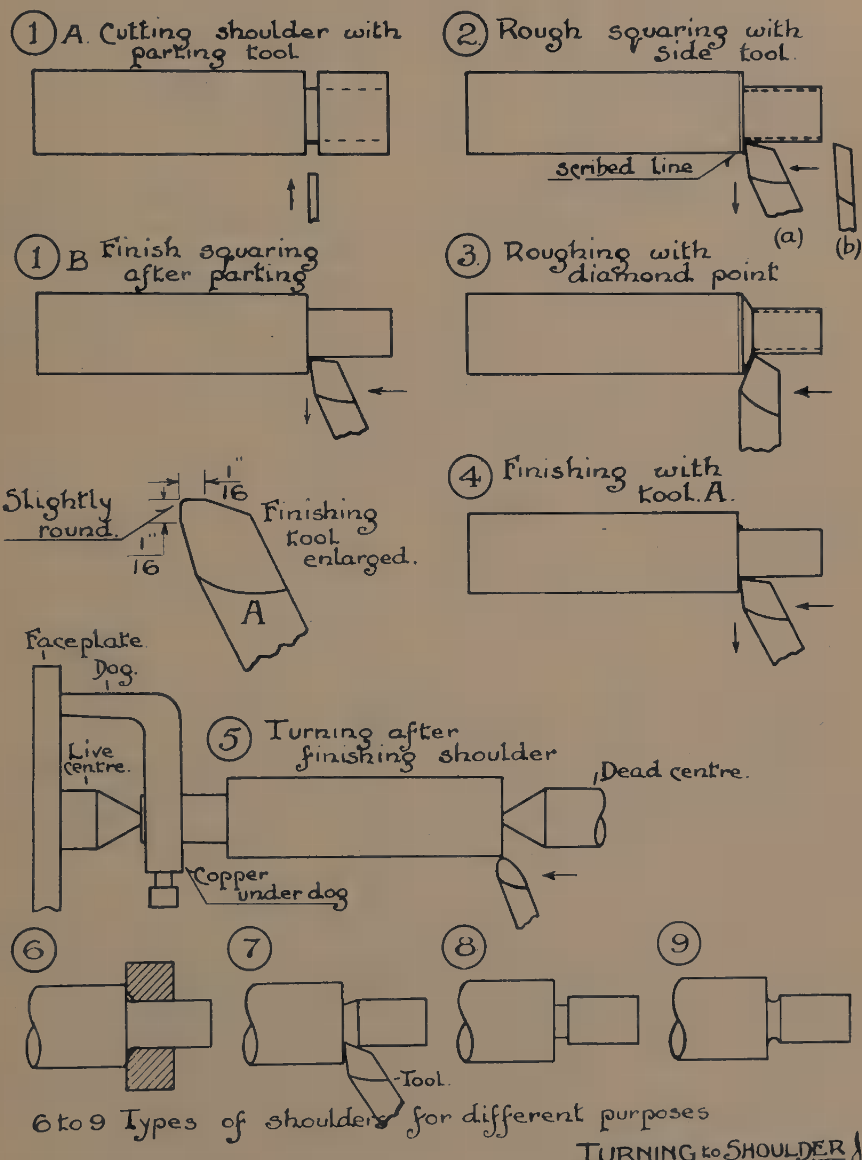
Various types of shoulders. Diagram (6) shows a shoulder with a "fillet" which gives a strong corner, but if the reduced portion has to be threaded to fit the nut as shown it would be necessary to countersink the nut, otherwise it would not fit up snugly to the shoulder.

Diagram (7) shows a shoulder recessed for clearance so that if it were threaded to the shoulder with a die, the shoulder would be clean in the corner and the nut would fit up to the shoulder tightly.

Diagram (8) shows another method of putting in "thread clearance" or "necking" as it is sometimes called. This cut is made with a parting tool.

Diagram (9). The round corner illustrated here makes a stronger corner than (7) or (8).

Depth of thread clearance should be equal to the pitch of a thread, so that the depth of the cut will be greater than the depth of the thread.


1 A. Cutting shoulder with parting tool
2 Rough squaring with side tool.
scribed line
(a)
(b)
1 B Finish squaring after parting
3. Roughing with diamond point
4 Finishing with tool. A.
Slightly round.
1"/16
1"/16
Finishing tool enlarged.
A
Faceplate
Dog.
Live centre.
5 Turning after finishing shoulder
Dead centre.
Copper under dog
6
7
8
9
Tool.
6 to 9 Types of shoulders for different purposes
TURNING to SHOULDER J.

TURNING TO DIAMETER AND KNURLING.

The making of a simple set screw will illustrate the sequence of operations for turning to diameter and introduce the beginner to the operation of knurling. The universal chuck is used to hold the work and the material used is machine steel. Just sufficient material should be allowed to protrude from the jaws of the chuck because if the work projects beyond the required distance a "chattered" surface will likely be produced.

Cutting speed. Proper cutting speed should be ascertained before starting the work; this is obtained by application of the lesson on cutting speeds (page 118). The belt is then moved to a suitable step on the cone pulley and the work rough and finish squared as shown in diagram (3). Before turning to diameter as shown in diagram (4) it is necessary to mark the work by first coating it with copper sulphate and scribing the line the correct distance from the end with scriber and rule or Hermaphrodite calipers as shown on page 55.

After rough turning and finish turning by taking a very light cut the next shoulder is marked and the stock is turned down to size to the shoulder diagram (5). (See methods on page 63).

Diameter of work for threading. The tendency with the average beginner is to turn parts that have to be threaded, oversize. If a plain piece of stock the exact size of a hole cannot enter it without force being applied surely an oversize piece of stock cannot enter the hole. The same applies to threaded work. It is much easier to make the diameter of the work to be threaded slightly smaller than the nominal size, so that when threaded with the die it will fit easily into the tapped hole.

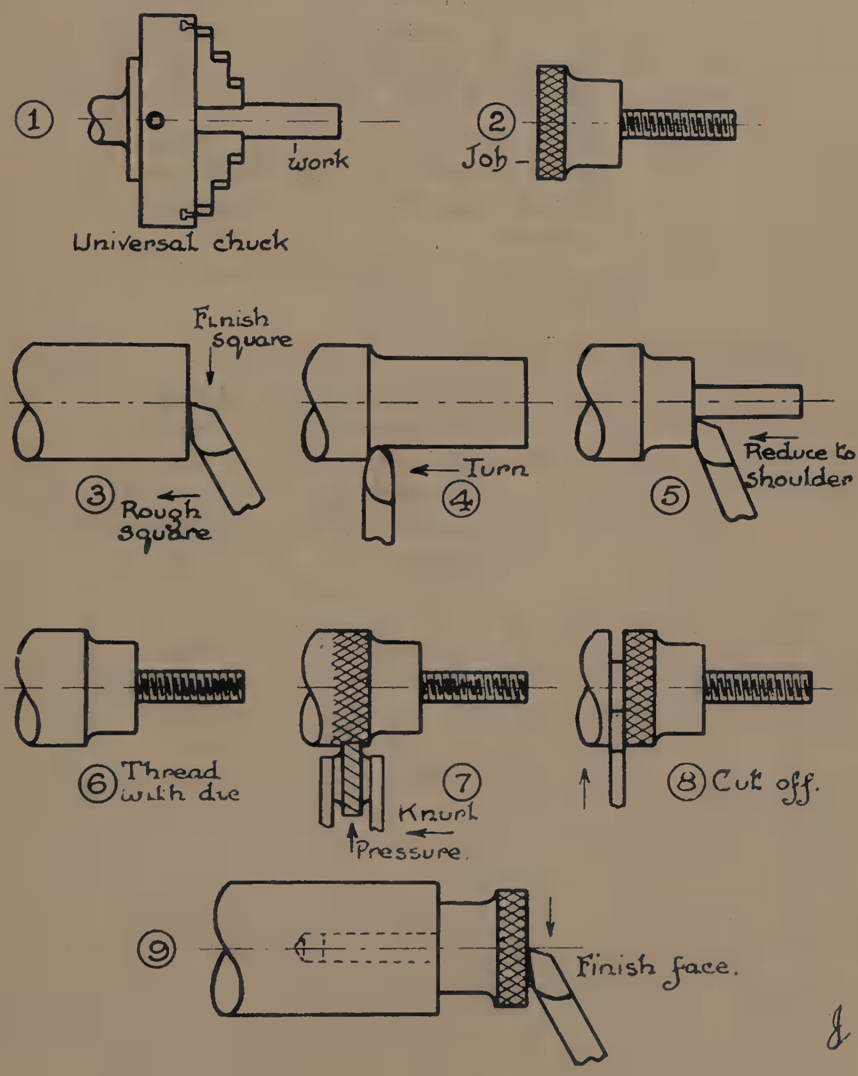
The threading as shown in diagram (6) is dealt with on page 21.

Knurling. Diagram (7). When a suitable knurling tool is selected it should be set up at right angles to the work and the knurls fed into the work while it rotates. Do not feed the knurl until a full diamond appears on the work. Use lard oil and usually one "pass" over the work is sufficient.

Cutting off. A parting tool may be used to cut off the stock as shown in diagram (8). It should cut a distance from the chuck less than the diameter of stock. Some beginners have trouble in using a parting tool, chiefly because they do not feed the tool in steadily. Light cutting tends to cause chatter. Use plenty of lard oil or cutting compound on the tool while cutting.

Finish facing. If a finer finish than that left by the parting tool is required, the work may be threaded into a suitable holder, which can be held in the chuck as shown in diagram (9).

Sequence of operations. There are many ways of doing work and the beginner is advised to study the order of operations on the work before starting. This sheet illustrates the sequence or order of carrying out the operations in the making of the set screw shown in diagram (2).


1
work
Universal chuck
2
Job
Finish square
3
Rough square
Turn
4
Reduce to shoulder
5
6
Thread with die
7
Knurl
Pressure.
8
Cut off.
9
Finish face.
J

FACING, TURNING AND RECESSING CAST IRON.

Castings as they are received from the foundry are not perfectly round and sometimes they have projecting pieces of metal which should be ground off. This operation is known as "snagging". Cast iron is a soft metal and easy to machine, but it has a very hard skin on the outside, which has to be removed first by a reduced cutting speed. Castings are often pickled to loosen particles of sand and to make machining easier.

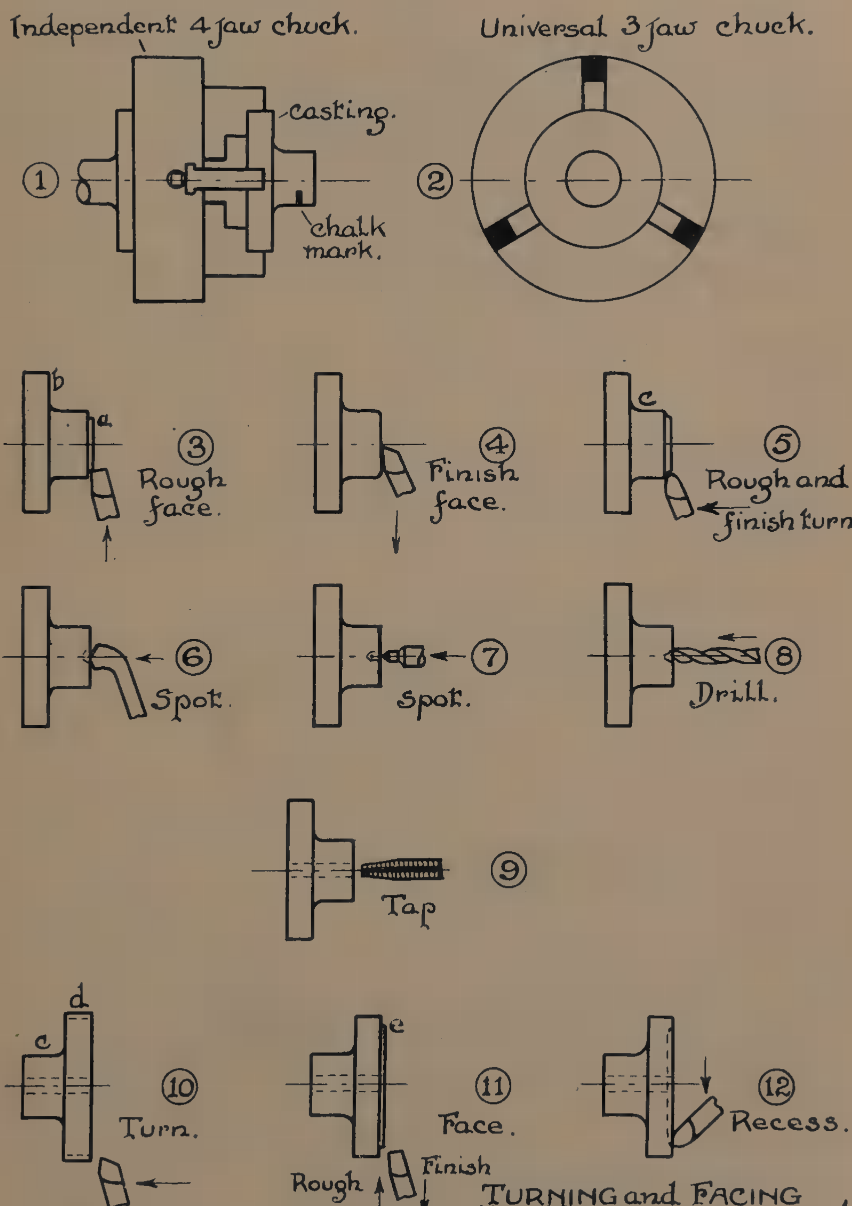
The job shown in diagram (1) is best set up in a 4-jaw Independent chuck because it is possible to adjust the jaws independently and hold the work so that it will run true. The beginner will find difficulty at first in using an "independent" or 4-jaw chuck and it is perhaps advisable for him, if the work is not very much out of round, to use a 3-jaw universal chuck, as shown in diagram (2).

To true work as held in diagram (1). Hold a piece of chalk steady against the work in rotation and where the chalk marks the work will be a high spot. The jaws must be adjusted until the chalk marks regularly around the work. When the work is running true, a rough facing tool is used to cut off the hard skin. The tool should be so placed so as to cut approximately at right angles to the skin as shown in diagram (3). Afterwards finish facing as in diagram (4). Faces (a) and (b) may be finished in this way, then (c) can be turned as in diagram (5).

Spotting before drilling. If a small drill were used without first "spotting" the face it would have a tendency to spring off the centre of rotation of the work and probably break the drill or drill the hole out of line. A spotting tool as shown in diagram (6) may be used, held in the tool post or an ordinary combination drill which is short and rigid as shown in diagram (7). Once a slight conic recess has been made in the work the drill will follow in the true location as shown in diagram (9). After tapping as explained on page 22, the work can be held in the chuck on the surface (c) and the part (d) turned, while the face (e) is turned and faced. (See diagrams 10, 11).

Facing. It is advisable when facing to lock the carriage and have the compound rest in position on the angle, so that the tool can be fed into the work and finish faced by operation of the cross slide, which will make the face (e) flat.

Recessing. Diagram (12). If the face (e) has to rest on a flat surface in use, it is advisable to recess it, so that the points of bearing are as far away from the centre as possible making it steady in use.



TURNING and FACING CAST IRON.

TURNING AND DRILLING BRASS.

To turn brass. Brass is a copper zinc alloy, and ranges in hardness from soft yellow brass to hard bronze. The work is turned at high speed and tools are used with no rake, owing to the tendency of the tool to dig into brass because of its softness. For turning, a sharp pointed tool is used with a small round nose as shown in diagram (2), and a nice finish can be obtained with a fine feed machined dry.

Diagram (1) illustrates a job in the form of a small match box, which involves the carrying out of the following operations:—Turning, Squaring, Drilling, Knurling, Cutting off and the making of a simple push fit.

Diagram (2) shows the first operation with the work driven with a 3-jaw universal chuck. It is necessary to turn the work to the correct diameter to obtain a true running surface before knurling.

Diagram (3) shows the spotting operation which can be accomplished with a combination drill held in the drill chuck in the tailstock spindle or a spotting tool held in the tool post. This operation is necessary to provide a correcting aligned centre for the drill.

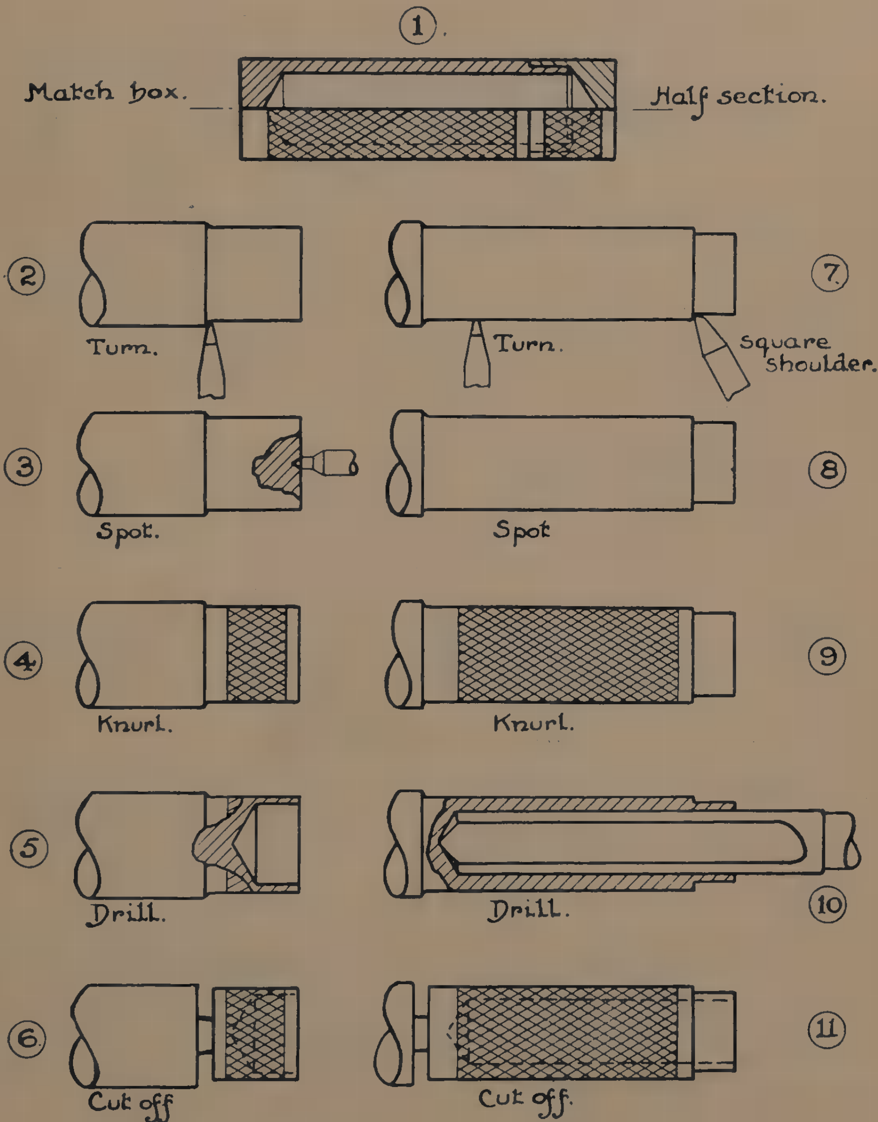
Diagram (4) shows the knurling operation. It is comparatively easy to knurl brass, owing to its softness. Use a fine feed and one pass over the work will produce a good knurl.

Diagram (5) shows the drilling of the brass. It is better to use a straight fluted drill for this operation because it does not dig into brass as a twist drill does. If a straight fluted drill is not available a twist drill can be used with a small flat ground at the cutting edges parallel to the axis of the drill (see page 36 on drills).

Diagram (6) shows the cutting off operation. If the cutting edge of the parting tool is slightly inclined to the axis as shown, the work will be cut off clean without leaving a projection on the finished work as it is separated.

Diagram (7) shows the turning and squaring of the body. The squaring tool has a small 60° angle at the point. It is set in such a position that the cutting side is slightly inclined towards the headstock to undercut, so that when operated outwards from the work a square shoulder and face is obtained by the cross feed. *Note.* Fit reduced shoulder by trial to the hole drilled in the head.

The operations shown in diagrams (8), (9), (10) and (11) are similar to those previously explained. If a high polish is required it is best to polish with abrasive cloth before knurling.



TURNING and DRILLING BRASS. 8.

USE OF COMPOUND SLIDE REST.

Carbon tool steel as it is purchased in rods or bars is usually annealed, which saves much time before machining. The stock can be cut off in a power saw or nicked with a file and broken off in the vise; afterwards it is advisable to grind the end before squaring. It is necessary to be quite sure that the steel is of the correct carbon content, otherwise the time spent machining will be wasted, because the steel must be suitable for the kind of work it has to do.

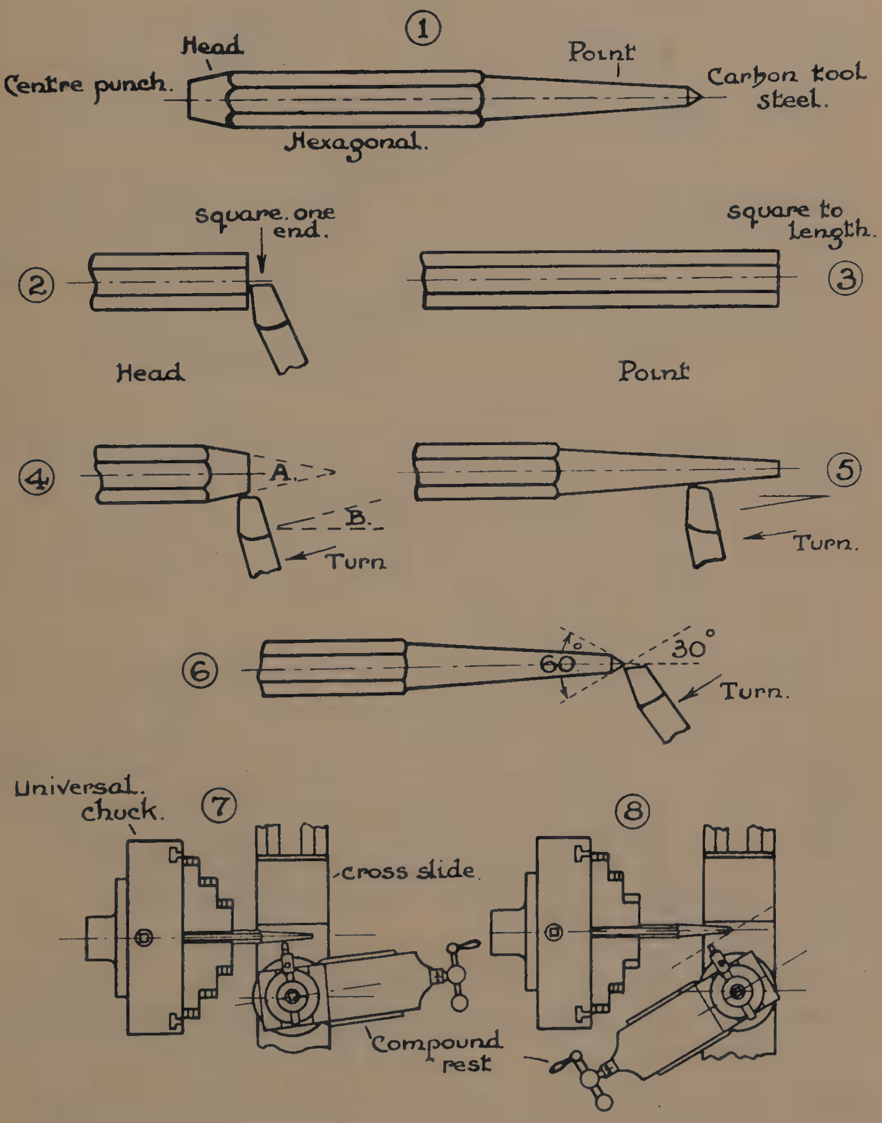
Carbon tool steel is so expressed because most of the best cutting tools to-day are made of *High speed steel* and it is necessary to differentiate between the two kinds of tool steel. Carbon tool steel is not easy to turn, it offers an increased resistance to cutting which is quite noticeable after machining machine steel. The tools therefore have a big cutting angle to support the cutting edge.

Cutting speed. It is advisable to look up suitable cutting speeds in tables provided (see page 158) and calculate the proper R.P.M. for the lathe before starting to work, otherwise the tool will soon lose its cutting edge.

Cutting lubricant. A cutting lubricant should be used when turning steel to prevent excessive friction, and to conduct away the heat, thus preserving the point of the tool and producing a smooth finish on the work. Lard oil or some other cutting compound which can be purchased ready mixed is suitable for a cutting lubricant.

Diagram (1) shows a centre punch which will illustrate the turning of steel and the use of the compound rest. After squaring as shown in diagram (2) it is necessary to adjust the compound rest to the angle required as shown in diagram (4).

Setting the compound rest. Loosen the bolts holding it to the cross slide and swing it to a position so that the compound rest screw is parallel to the lathe alignment. Note the angle opposite the zero mark, then swing it a number of degrees equal to one-half the included A, diagram (4), as shown by angle B which is the angle to which compound rest is set and fasten securely in position. It is convenient to cut the angle as shown in diagram (4) from the right side, operating the screw on the compound rest with the right hand similar to diagram (7). If the compound rest were swung to the left as shown in diagram (8) to cut the smaller angles, the operator's hand would be too close to the chuck; therefore for the smaller angles it is better to cut them when the compound rest is in position as shown in diagram (7) operating the screw with the right hand.



TURNING TOOL STEEL; COMPOUND REST

LATHE CENTRE ALIGNMENT.

Approximate method of checking lathe centre alignment. Setting the centre of a lathe in alignment by approximate methods are shown in diagrams (1) and (2). These methods of checking may be satisfactory for some work, but generally, it is better to set the lathe so that work can be done at least to one thousandeth of an inch variation in diameter.

Accurate method, diagram (3). If a proof bar is placed between the centres of a lathe, and a lathe test indicator is set up in the tool post, any offset of the centres will readily be noted when the indicator is moved along the bar while it is in rotation.

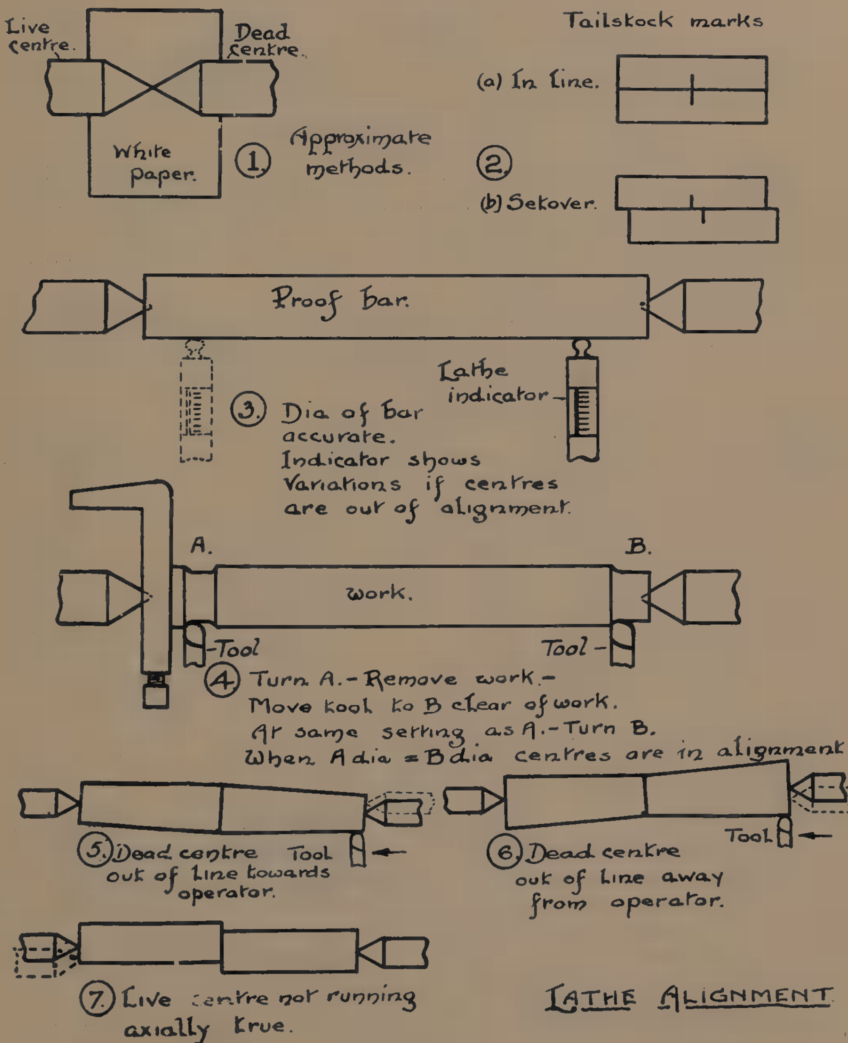
Note.—A proof bar is accurate to diameter throughout.

Accurate method, diagram (4). Take a piece of stock with centre holes in it and mount on the lathe centres. Be quite sure that the centres and sleeves are in the same position as when they were turned or ground; this is usually denoted by a mark on the spindle, sleeve and centre. Press the centres down solidly in the tapered holes of the lathe spindle and tail-stock spindle, then adjust lightly the pressure of the centres on the work and lubricate the dead centre.

Turn a portion of the shaft at A wide enough to allow the caliper or micrometer to measure the diameter. Do not disturb the setting of the tool but remove the work from between the centres and move the carriage towards the dead centre to allow the work to be replaced on centres. Turn a portion at B. Now if the lathe centres are in alignment, the diameter of the work at A and B will be the same. If any variation of diameter is noted the lathe centres are not in alignment and must be offset until the trial cuts at A and B produce the same diameter in the work at each end.

Centres out of alignment will produce work as shown in diagram (5) or (6) when the work is turned half way from each end by reversing the work on centres.

Live centre not running true. Occasionally the live centre or sleeve may be damaged or small chips may be lodged between them. This will cause the centre not to run axially true, and will tend to produce work as shown in Diagram (7). It is therefore very important to clean the spindle, sleeve, and centre, before assembling and exercise care in preventing them from damage.


Live centre.
Dead centre.
White paper.
1. Approximate methods.
Tailstock marks
(a) In line.
2.
(b) Setover.
Proof bar.
Lathe indicator
3. Dia of bar accurate.
Indicator shows variations if centres are out of alignment.
A.
B.
work.
Tool
Tool
4. Turn A.—Remove work.—
Move tool to B clear of work.
At same setting as A.—Turn B.
When A dia = B dia centres are in alignment
5. Dead centre out of line towards operator.
Tool
6. Dead centre out of line away from operator.
Tool
7. Live centre not running axially true.
LATHE ALIGNMENT

TAPER TURNING.

Diagram (1) shows the various parts of a taper.

(a) Taper per foot.
(b) Diameter of large end.
(c) Diameter of small end.
(d) Total length of work between centres.
(e) Length of tapered portion.
(f) Angle of the taper.

Diagram (2) and (3)—*Comparative setover of equal tapers.* Diagram (2) shows two pieces of work of equal taper but not of equal length. Diagram (3) shows that to put (a) and (b) in alignment with the lathe the setover of the longer piece (b) is greater than the setover of the shorter piece (a).

Tool position for taper turning. The tool should be set exactly on centre to produce straight work as shown in Diagram (4). If the tool is set above the centre as shown in Diagram (5) curved work will result.

Method (1)—*To set over the tailstock* to the distance calculated, unclamp the tailstock and turn the adjusting screws to move the dead centre towards the operator. Watch the marks on the tailstock and measure the setover distance with dividers or rule.

Method (2)—A more accurate method of offsetting the tailstock is to use the calibrations in 1/1000 of the cross slide. Run the cross slide in towards the work until the tool pinches a piece of paper as shown in Diagram (6). Next take up the "Backlash" or lost motion in the cross feed screw and note the graduation on the collar. Turn the screw of the cross slide until the setover amount is registered, then adjust the tailstock by the adjusting screws until a piece of paper is pinched against the tool setover shown in diagram (7). This is the required offset, now lock the tailstock in position.

Note.—Be quite sure that the lathe is in perfect alignment before measuring the setover.

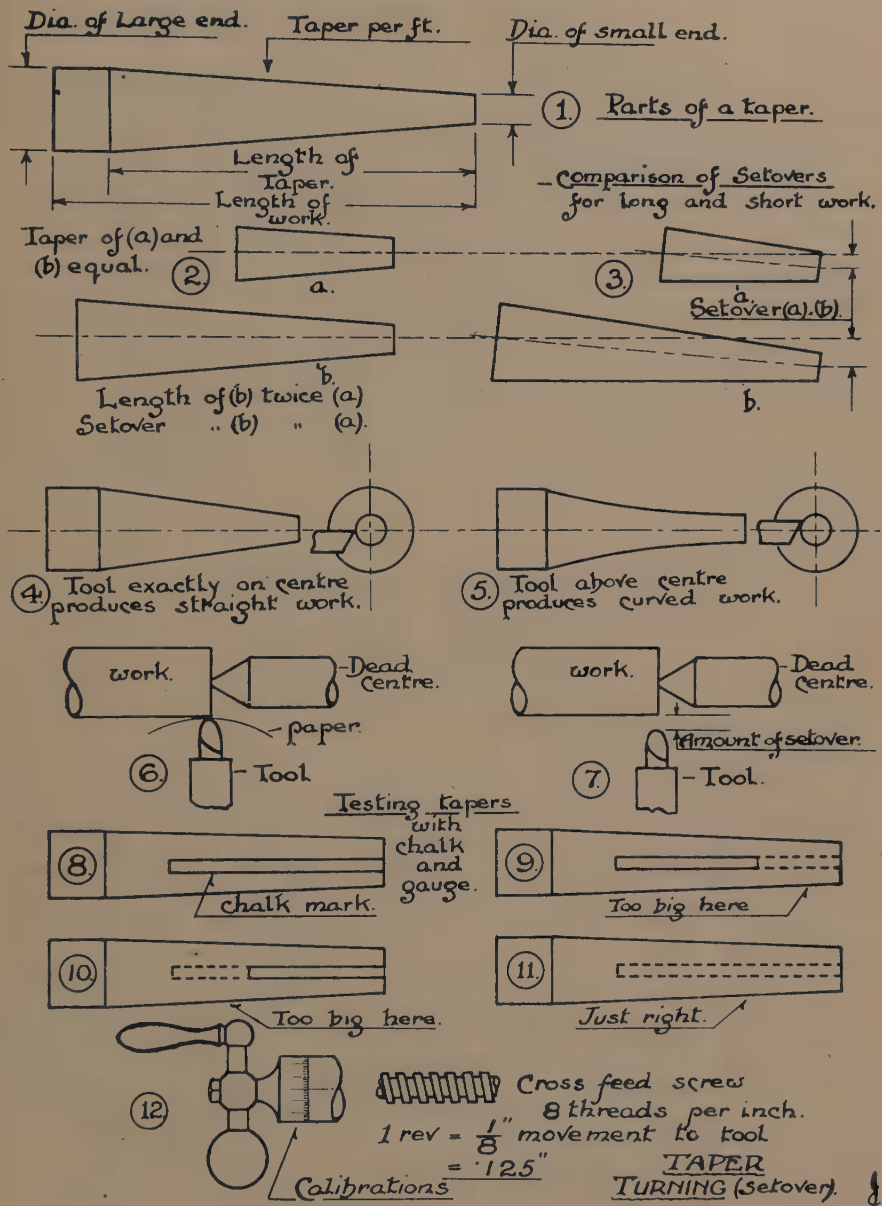
Testing the taper. External tapers are tested to an external or "Taper ring gauge" or to the sleeve or spindle it is intended to fit. To do this mark chalk lines or Prussian Blue oil paint on the work as shown in Diagram (8) and partly turn in the gauge. If the chalk marks rub off as in Diagram (9) it will be too big at the small end, if, as in Diagram (10) too big at the large end, while Diagram (11) shows a satisfactory test with the chalk mark rubbed off evenly.

To duplicate a taper place the tapered piece between centres and use a test indicator to check correct setover to produce the same taper.

Fitting the taper. If the taper does not fit it may be necessary to make a slight adjustment in the setover and for this reason the work should always be tested while oversize, then finished to correct diameter when the taper has been proved to fit. Slight variation of fit can be remedied by a little filing.

Measuring the setover by the cross slide. If the cross feed screw has 8 threads per inch as shown in Diagram (12) then—

1 revolution of screw$=\frac{1}{8}''$ or $.125''$.



If the graduated collar is marked in 1/1000″ its periphery would contain 125 divisions, therefore—a setover of .157 would give

I revolution of screw, or	.125″
and 32 small divisions or	.032″
Total	.157″

THE MICROMETER.

The micrometer is designed to measure accurately to thousandths of an inch and a micrometer can also be provided with a vernier to read to ten thousandths of an inch. To-day, it is not sufficient to rely on the correctness of reading measurements by checking line to line as is the case with the steel rule. Science has introduced mathematical arrangements whereby one is assured of a mechanical accuracy. The screw thread is the mechanical means provided to give the fine movements of the micrometer screw so that in conjunction with its fine divisions the micrometer will read to thousandths of an inch.

Diagram (1) shows a diagonal scale which, by the application of the Principle of Proportion, we are enabled to read to one hundredth part of an inch. The principle underlying its use with the micrometer is shown in its primary form in Diagram (2). If a triangle is constructed, as is shown, and the base (a.b.) is divided into any number of parts (say 25) then the vertical line (e.f.)$=\frac{5}{25}$ of (b.c.). Any screw thread is similar to an inclined plane wrapped around a cylinder, as shown in Diagram (2) where (a.b.) equals the distance around the cylinder. If we suppose that—

(b.c.)$=\frac{1}{40}''$ or the pitch of a micrometer screw
then—(e.f.)$=\frac{5}{25}$ of $\frac{1}{40}''$ or $\frac{5}{25}$ of $.025''=.005''$.
so that the first vertical line$=\frac{1}{25}$ x $.025''=.001''$.

The micrometer construction—Diagram (3). *The spindle* of the micrometer, which is concealed, has 40 threads per inch, so that, if the spindle were rotated once, it would move a distance of $\frac{1}{40}''$ or .025 or 25 thousandths.

The Thimble (*T*) has a knurled face, to facilitate its rotation with the fingers, and has on its beveled edge 25 marked divisions in groups of 5, so that, as the thimble rotates equally with the screw, 1 revolution equals the movement of the screw, or 25 thousandeths. If starting from the mark O on the thimble, in line with the line on the barrel we move the thimble to the next mark in line with the barrel, the screw will have moved $\frac{1}{25}$ of $.025''=.001''$.

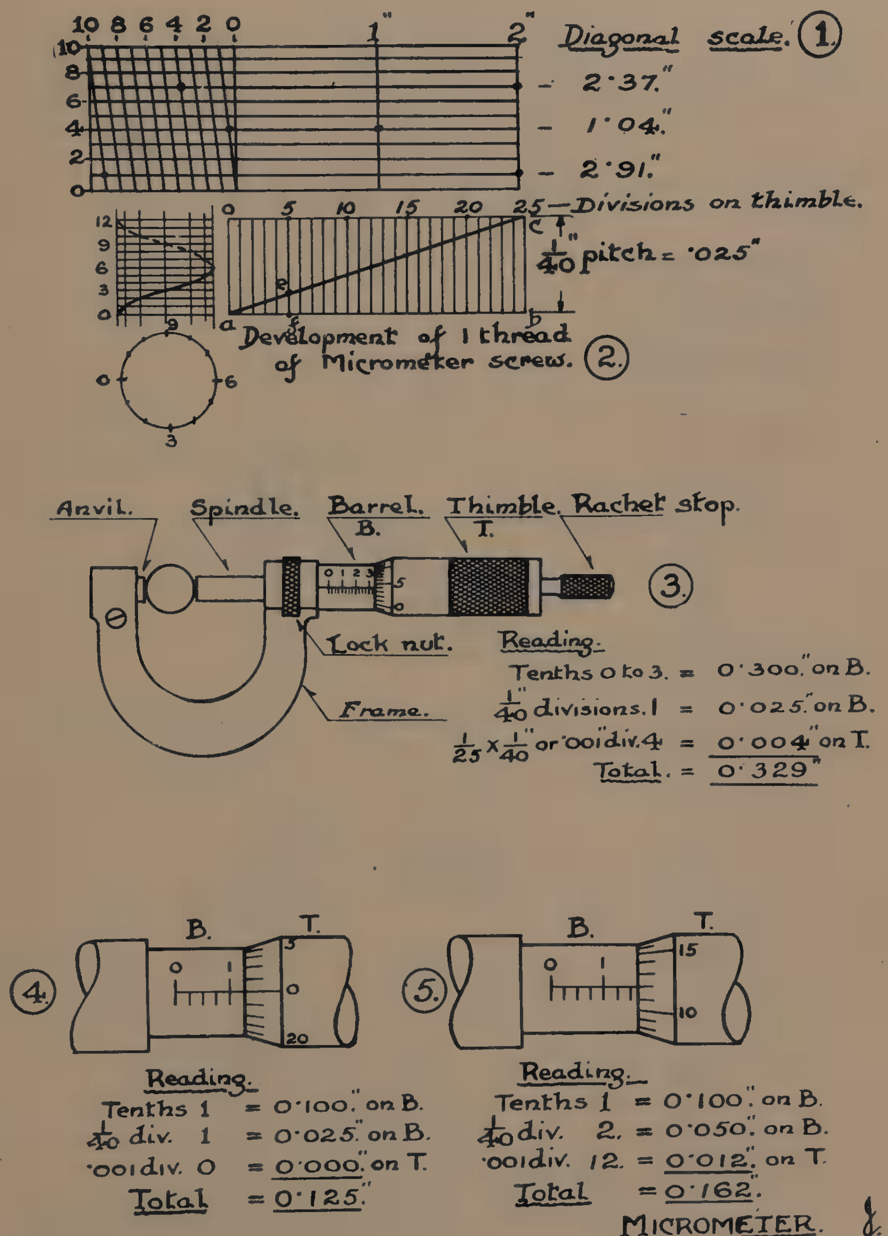
The Barrel has a line from which the thimble measurements are checked, and this line is divided into small divisions and units, as from 0 to 1, which includes 4 small divisions. To find what these divisions represent, move the thimble till 0 on the thimble corresponds to 0 on the barrel. Now, turn the thimble 1 revolution from 0 to 0 and you will observe that small divisions of the barrel equal 1 revolution of the thimble and screw, or $.025''$ or $\frac{1}{40}''$.

Since 1 small division on the barrel$=\frac{1}{40}''$
then 4 " " " " $=\frac{4}{40}''=\frac{1}{10}''$.

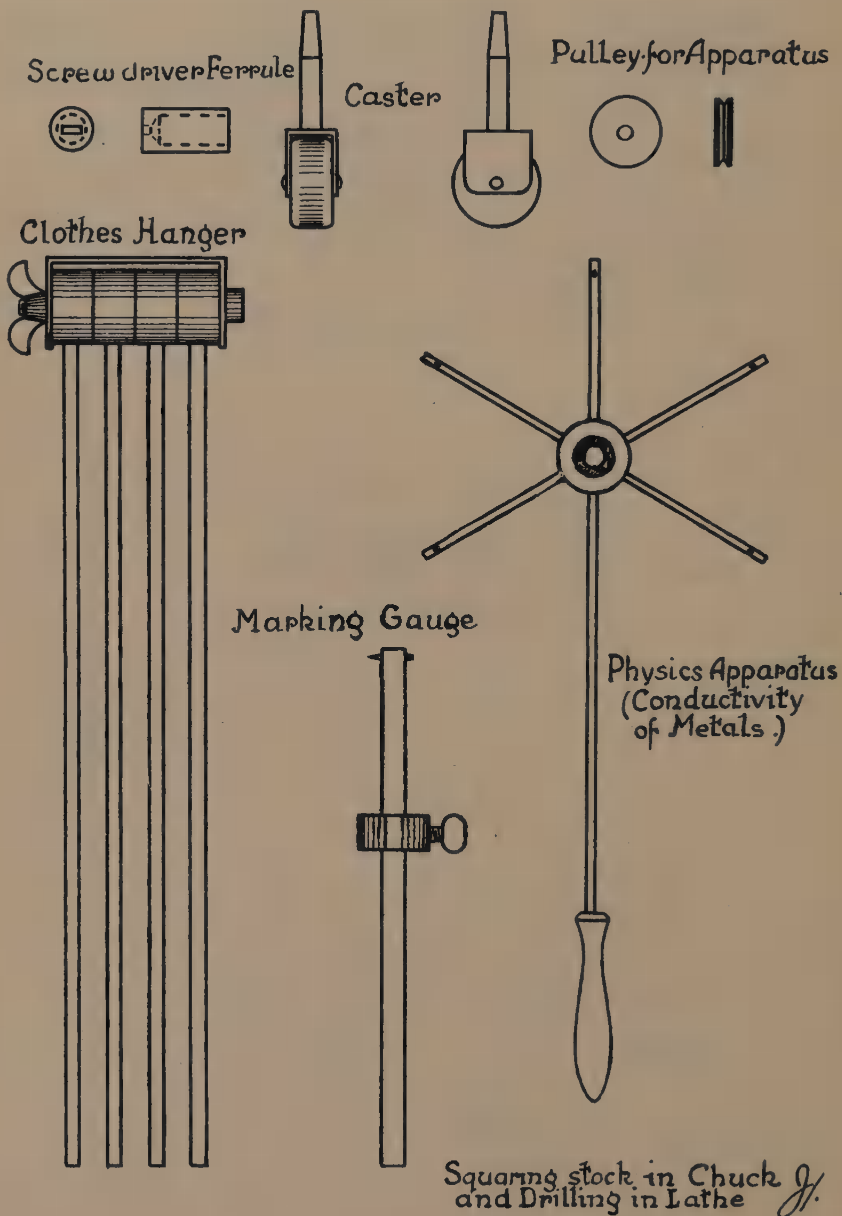
To read micrometer. Use it as illustrated in Diagrams (4) and (5). First note the number of tenths exposed, then the number of fortieth divisions that is—

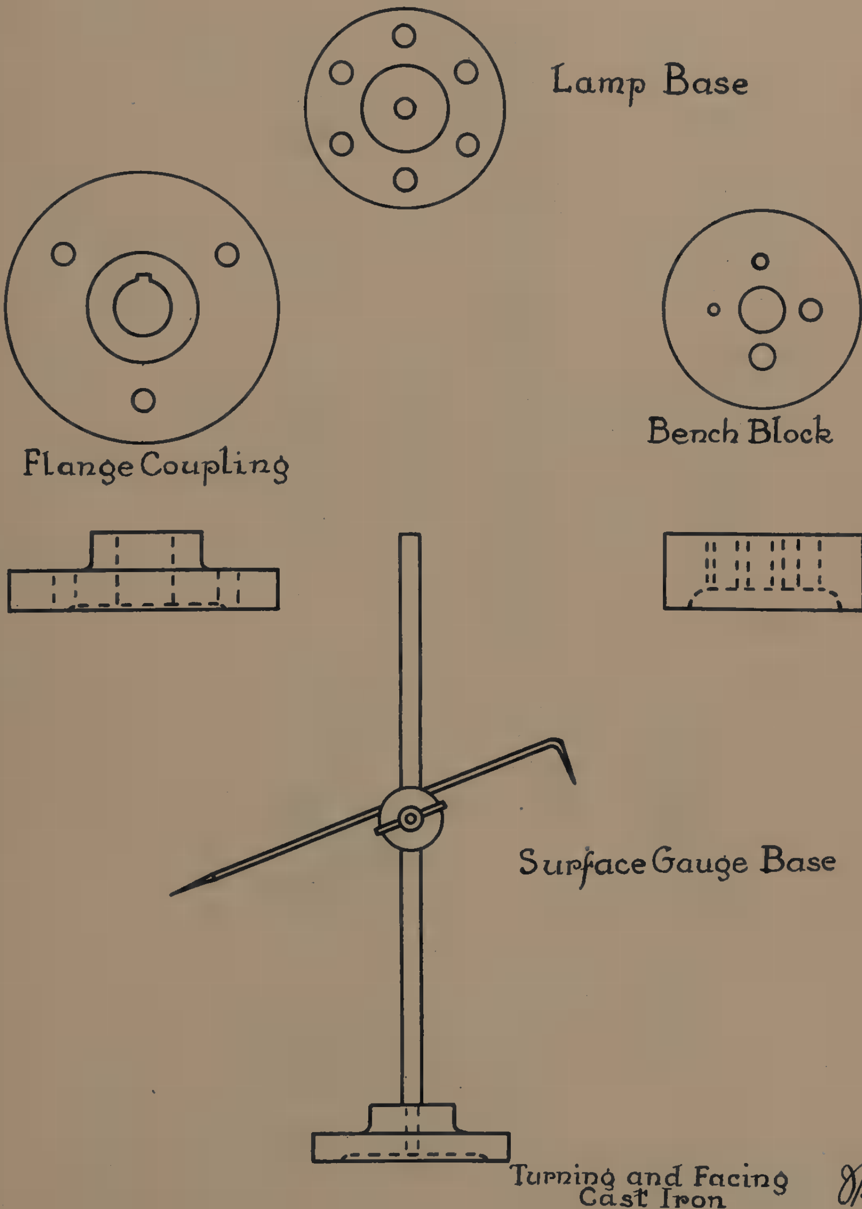
$\frac{1}{40}=.025$ $\frac{2}{40}=.050$ $\frac{3}{40}=.75$ $\frac{4}{40}=.1$

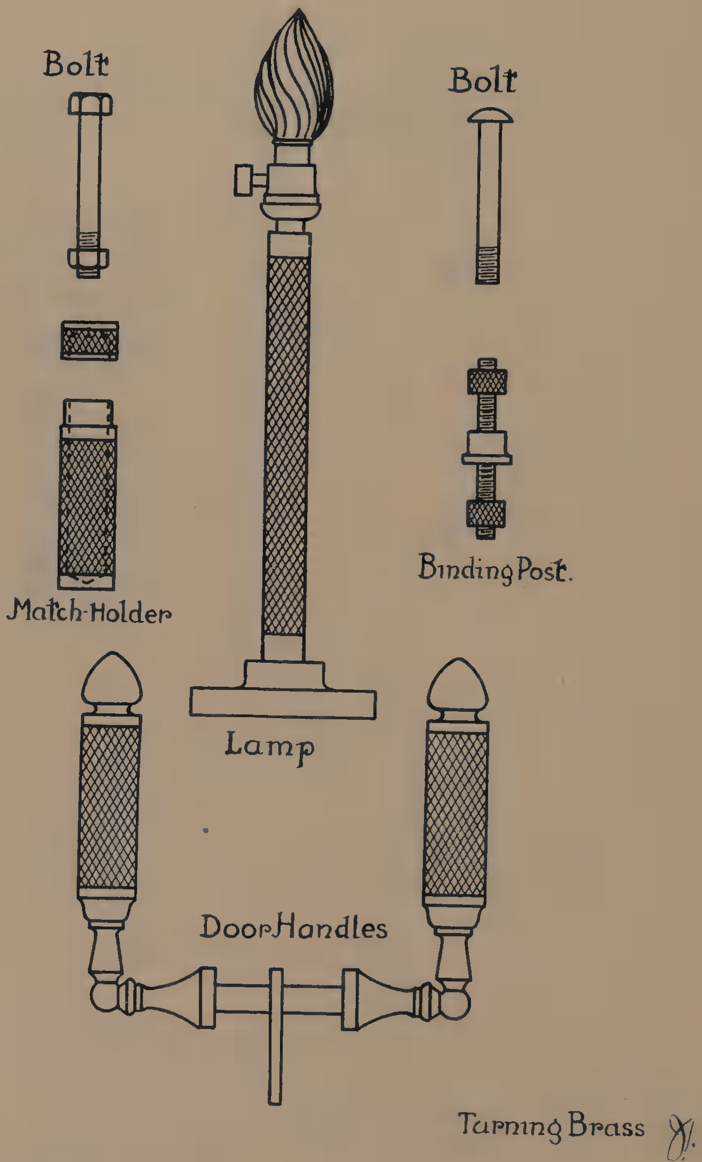
Finally, read the number of divisions on the thimble and then add all together


10 8 6 4 2 0
1"
2"
Diagonal scale. (1)
2·37."
1·04."
2·91."
0 5 10 15 20 25—Divisions on thimble.
12
9
6
3
0
$\frac{1}{40}$" pitch = ·025"
Development of 1 thread of Micrometer screw. (2)
Anvil.
Spindle.
Barrel. B.
Thimble. T.
Rachet stop.
(3)
Lock nut.
Frame.
Reading.
Tenths 0 to 3. = 0·300." on B.
$\frac{1}{40}$" divisions. 1 = 0·025." on B.
$\frac{1}{25}\times\frac{1}{40}$" or ·001" div. 4 = 0·004" on T.
Total. = 0·329"
(4)
B.
T.
Reading.
Tenths 1 = 0·100." on B.
$\frac{1}{40}$ div. 1 = 0·025." on B.
·001 div. 0 = 0·000." on T.
Total = 0·125."
(5)
B.
T.
Reading.
Tenths 1 = 0·100." on B.
$\frac{1}{40}$ div. 2. = 0·050." on B.
·001 div. 12. = 0·012." on T.
Total = 0·162."
MICROMETER.

PROJECTS

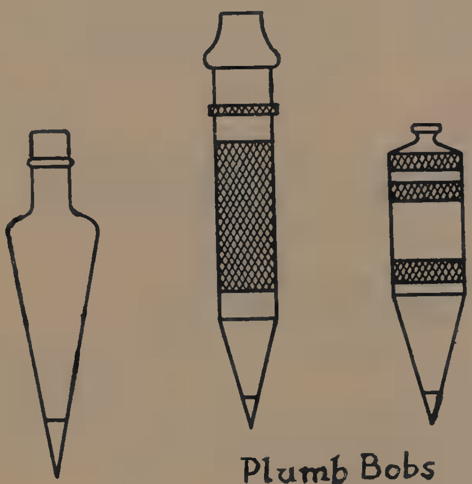

Screw driver Ferrule
Caster
Pulley for Apparatus
Clothes Hanger
Marking Gauge
Physics Apparatus
(Conductivity
of Metals.)
Squaring stock in Chuck
and Drilling in Lathe


Lamp Base
Flange Coupling
Bench Block
Surface Gauge Base
Turning and Facing
Cast Iron


Bolt
Bolt
Match-Holder
Binding Post.
Lamp
Door Handles
Turning Brass

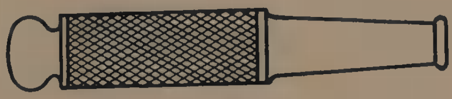
Centre Punch

Centre Punch



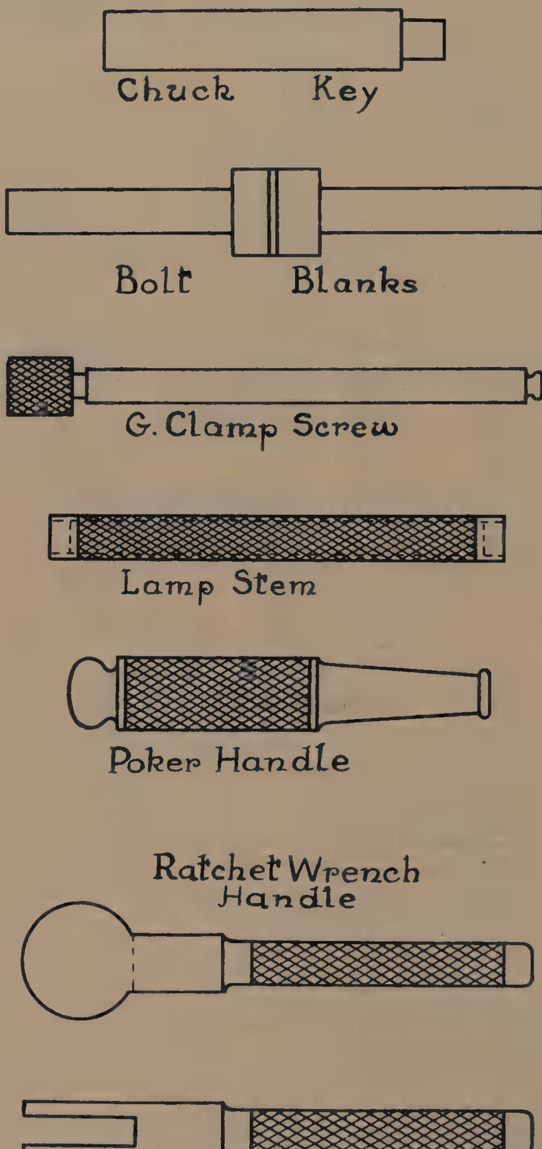
Plumb Bobs

Nail Punch

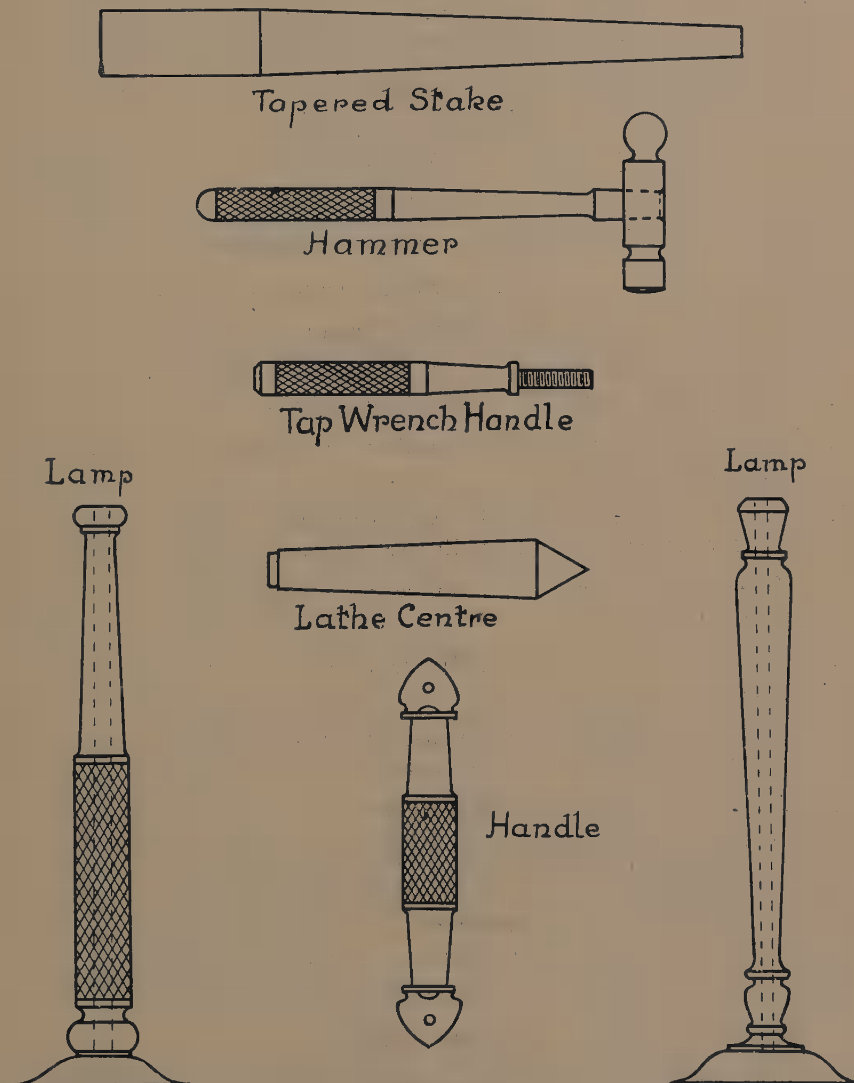


Poker Handle

Taper Turning with Compound Slide-Rest



Turning on Centres & Knurling 81.



Taper Turning (Set over Method)

QUESTIONS ON LATHEWORK.

1. What are the main parts of a lathe?
2. How many spindle speeds can be obtained on a lathe which is single back geared with a 4 step cone pulley?
3. Is the speed cone of a lathe fastened to the spindle? How can the spindle of a lathe be driven? pipe mandrin
4. How is the size of a lathe obtained?
5. In what different ways can lathework be driven? plateau
6. Why is the main spindle of a lathe made hollow?
7. What parts of a lathe would you oil before starting to work?
8. Why is one centre called a "dead" centre and one a "live" centre? Which centre should be hard? Why? centre mort
9. What are the names and uses of the various lathe tools?
10. Which is the safest and best position for the tool post when turning work held in a chuck?
11. What is the effect of a lathe tool being set on centre, below centre or above centre? Which is the best position and why?
12. When a tool is pressed into the work by chip pressure how can this defect be overcome?
13. When would you use (a) A Universal chuck? (b) An Independent chuck? (c) A Faceplate? plateau mandrin
14. What kind of a tool would be used for squaring work? How would the tool be placed in relation to the work?
15. What are the various methods of turning to a shoulder? épaulement
16. What do you understand by "sequence of operations"? Why is it advisable to plan operations before starting to work? méthode
17. What precautions are necessary in turning the following metals:—(a) machine steel, (b) cast iron, (c) brass, (d) tool steel?
18. Why is the nose of the main spindle of a lathe threaded?
19. What are the "ways" of a lathe used for?
20. If the tailstock of a lathe is offset or setover how would it be put back in alignment?
21. What is the danger if the reverse clutch is thrown in when a chuck is loose on the spindle nose?
22. Why is it necessary to square the end of stock before turning on lathe centres?

23. What method of Squaring may be adopted for (a) Stock of small diameter? (b) Stock of large diameter? Which has to be turned on lathe centres?

24. Why is it necessary to drill centre holes in stock? What is the shape of the hole, and what is the best tool to use to obtain it?

25. How is work centred in the lathe by "hand"? What precaution must be taken to prevent breaking the drill?

26. What precautions must be taken to prevent the "dead centre" of a lathe from being damaged when turning work between centres,

27. What causes the friction between the rotating work and the dead centre of a lathe?

28. Why is it necessary to exercise care in locating the centre of stock to be turned on lathe centres,

29. What tools may be used to locate the centre of stock? How are they used?

30. Why must lathe centres be in line? What is the effect if the lathe centres are out of line?

31. What precaution must be taken in setting up the sleeve and live centre in the lathe spindle?

32. How should work be adjusted between centres?

33. How are lathe centres "aligned" (a) Approximately? (b) Accurately?

34. What methods may be used to measure the setover of the tailstock for taper turning.

35. How can tapered work be tested for accuracy?

36. Which would require the greatest setover, a short piece of work or a long piece of work if both had the same taper per foot

37. How must the tool be set for taper turning? Why?

38. What is the relation between the operation of the micrometer and the operation of the crossfeed screw of a lathe with a graduated collar?

PLANING IN THE SHAPER

THE SHAPER.

The shaper. The shaper is used chiefly to produce flat surfaces. It is very suitable for small work while the planer is designed to operate on the larger work. The work may be held in the vise which is bolted to the work table or it may be fastened direct to the table itself.

There are many designs of shapers used, but of the column shapers similar to the one illustrated here, there are two types, geared shapers, and crank shapers.

The geared shaper. The ram is driven by a gear meshing with a rack on the bottom of the ram, also with a means for the quick return of the stroke.

The crank shaper illustrated here is driven by a crank motion with a means provided for the quick return of the stroke.

3 **Size of the shaper** is governed by the size of work the machine can do. A 16″ shaper will plane work 16″x16″x16″.

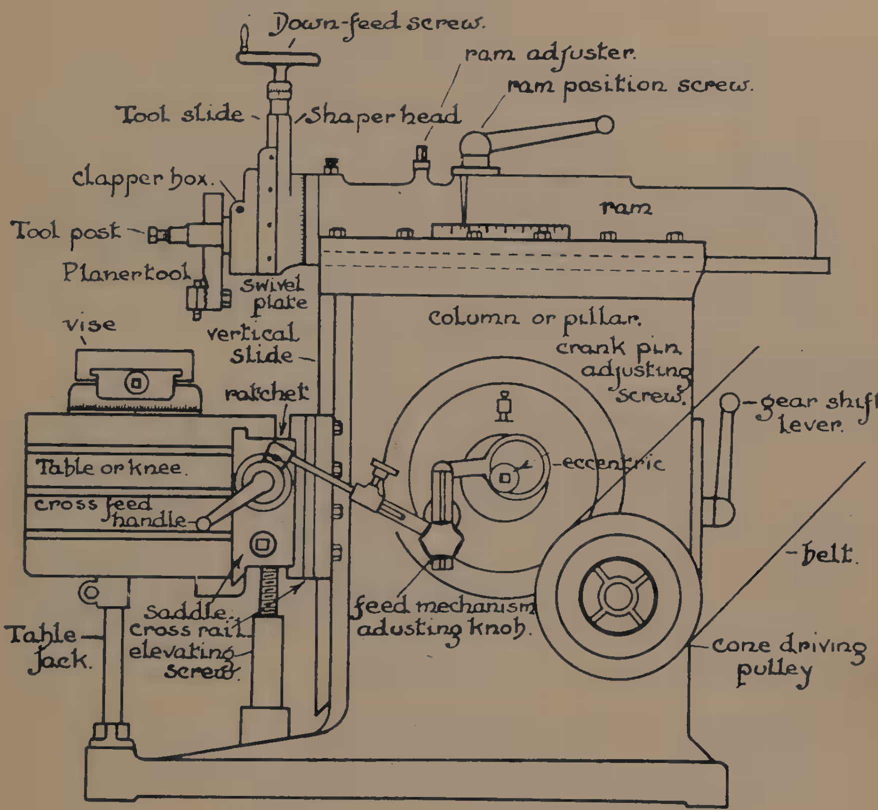
Transmission of power to the ram. The belt from the countershaft drives a cone pulley on the machine driving shaft. Inside the column there is a sliding pinion and gear which can be moved by the gear shift lever to connect a gear or a pinion on an auxiliary shaft giving the high and low speeds, so that the machine shown has 3 low speeds and 3 high speeds because the speed cone has three steps. The auxiliary shaft connects to the crank through the meshing of the gears of the auxiliary shaft and the outer part of the crank which has gear teeth. The crank pin moves in a slot across the face of the crank. If on the centre of the crank there is no "throw" the ram consequently does not move. If moved off centre of the crank through the crank pin adjusting screw there is a "throw" and this throw acting on the pin which moves in a slot of the driving lever, forces the driving lever to move or oscillate.

The driving lever is pivoted at the low end on its fulcrum and the other end of the lever is connected to the ram screw while the crank pin exerts pressure between the two points as the crank rotates.

lever

The ram now is forced to move backwards and forwards in a straight line and because the crank pin acts nearer the pivot of the driving lever in one portion of the crank rotation the ram *is given* the *quick return.*

The position of the ram with regard to the work depends upon the position in which the driving lever is connected to the screw inside the ram. If it holds at the front of the ram the stroke is near the column of the machine. If it holds at the back of the ram the stroke is further from the column.



THE SHAPER

The feed mechanism illustrated in the diagram receives its movement first from an eccentric driven by the crank spindle. The eccentric is connected by an eccentric strap to the reversing or rocking lever which rocks about a central pin. The face of the lever is tee slotted and a tee bolt adjusted by a knob can be fastened in any position required. If moved off centre the feed increases, and if put on the opposite side of its centre the timing of the feed changes.

The table can be raised or lowered by operating the elevating screw and can be moved away or towards the operator by hand through the crossfeed handle or mechanically through the feed mechanism.

THE FEED MECHANISM OF THE SHAPER.

The shaper is designed to move slowly on the forward or cutting stroke and quickly on the return or non-cutting stroke. The feed should operate when the tool is on the return stroke.

The direction of feed is governed by the way in which the tool is ground as can be noted by comparing diagrams (1) and (7). The tool moves in a straight line and the work must be moved in a direction at right angles to the direction of the cut as shown in diagrams (1) and (2).

Timing the feed. The feed can be made to act when the tool is cutting or when the tool is not cutting. If the feed occurs while the tool is cutting the feed mechanism would be operating under an unnecessary load, therefore it should always occur at the time that the tool is not cutting.

Mechanism provided for timing the feed. A rocking lever or reversing mechanism is operated from the centre of the crank rotation, and rocks back and forth about its centre at the same time that the ram moves backwards anl forwards. A Pawl which operates the feed ratchet is connected by a rod to the rocking lever, the rod end A being adjustable on or off centre on each side of the rocking lever.

The amount of the feed is governed by the distance A is adjusted off centre as shown in diagram (5). If A is fastened near the centre B the feed will be reduced but if A is fastened out from the centre the feed will be increased.

The forward stroke for tool A is illustrated in diagrams (1), (3) and (5).

(a) The tool is cutting forward diagram (1).
(b) The pawl is returning free diagram (3).
(c) The lever at A is moving counter clockwise diagram (5).

The return stroke.

(a) The tool is returning free.
(b) The pawl is feeding the ratchet diagram (4).
(c) The lever at A is moving clockwise diagram (6).

The effect of the tool on the feed mechanism. Diagrams (7) and (8) show the tool B cutting in the opposite manner from the tool A in diagrams (1) and (2). This means that if A diagram (5) were allowed to remain in the same position on the rocking lever the feed would occur when the tool B is cutting.

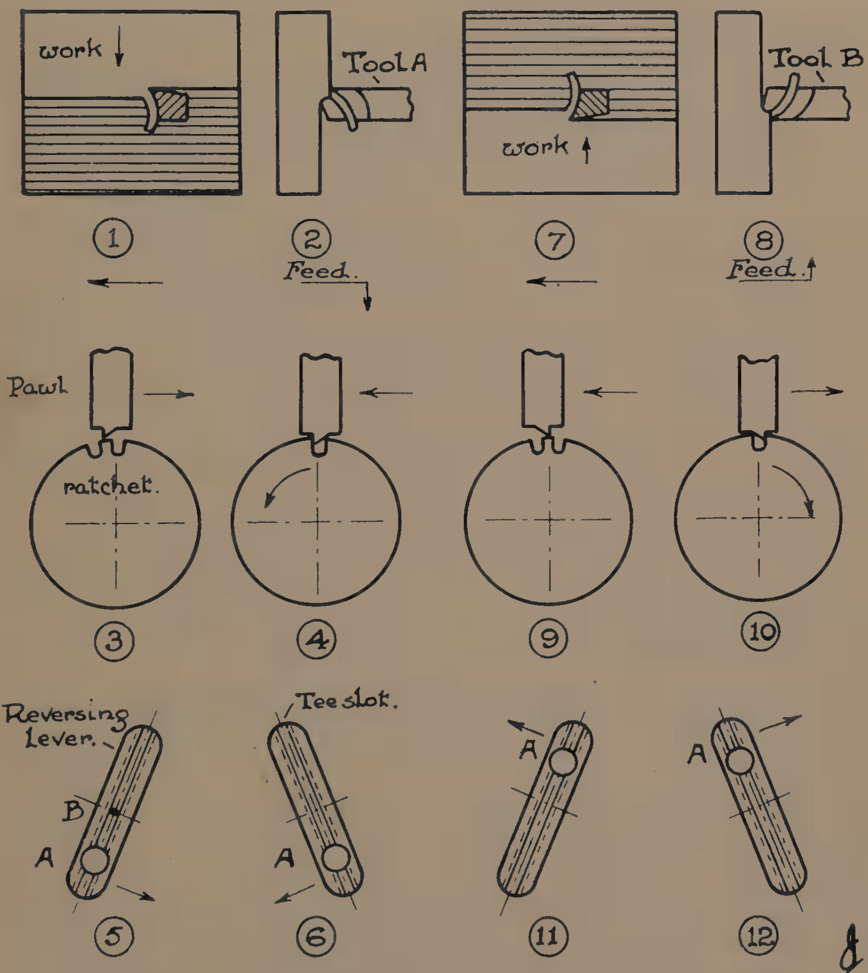
To correct the timing of the feed for the tool B, the point A is moved to the opposite end of the lever as shown at A in diagram (11).

The forward stroke for tool B is shown in diagram (7), (9) and (11).

(a) The tool is cutting forward diagram (7).
(b) The pawl is returning free diagram (9).
(c) The lever at A is moving counterclockwise diagram (11).

The return stroke.

(a) The tool is returning.
(b) The pawl is feeding the ratchet diagram (10).
(c) The lever at A is moving clockwise diagram (12).



SHAPER FEED MECHANISM.

PLANING A SMALL BLOCK IN THE SHAPER.

The block shown in Diagram (1) is to be machined all over. Owing to its size it is one of the simplest operations for a beginner. The vise which is fastened by bolts to the top of the knee of the shaper is used to hold the work.

Holding castings in the shaper vise. The surfaces of rough castings are very hard and irregular and if placed in the vise they will mark the faces of the vise jaws and make them rough and inaccurate for fine work.

It is advisable when the work is rough to place a piece of cardboard between the work and the face of the vise, this accomplishes two things:—

(1) It holds the work securely preventing slipping.

(2) It forms a cushion for the various irregularities on the work, and therefore the vise exerts a pressure over a greater area.

Direction of cut on work. It is quicker to plane a surface cutting in line with its length than in line with its width, although the work is far more rigid when being cut against the vise jaw; but the friction when held between the jaws is usually sufficient to hold the work when cutting lengthwise.

Order of operations. The sequence or order of operations is shown in diagram (1) and detailed in the various positions of the work as shown in diagrams (2) to (8).

Set up work in the vise as shown in diagram (2) with cardboard between it and each face of the vise. Test to see that the block rests solidly on the parallel and with a surface gauge test to see that the upper surface is approximately parallel with the top of the vise. Adjust the speed and stroke of the machine.

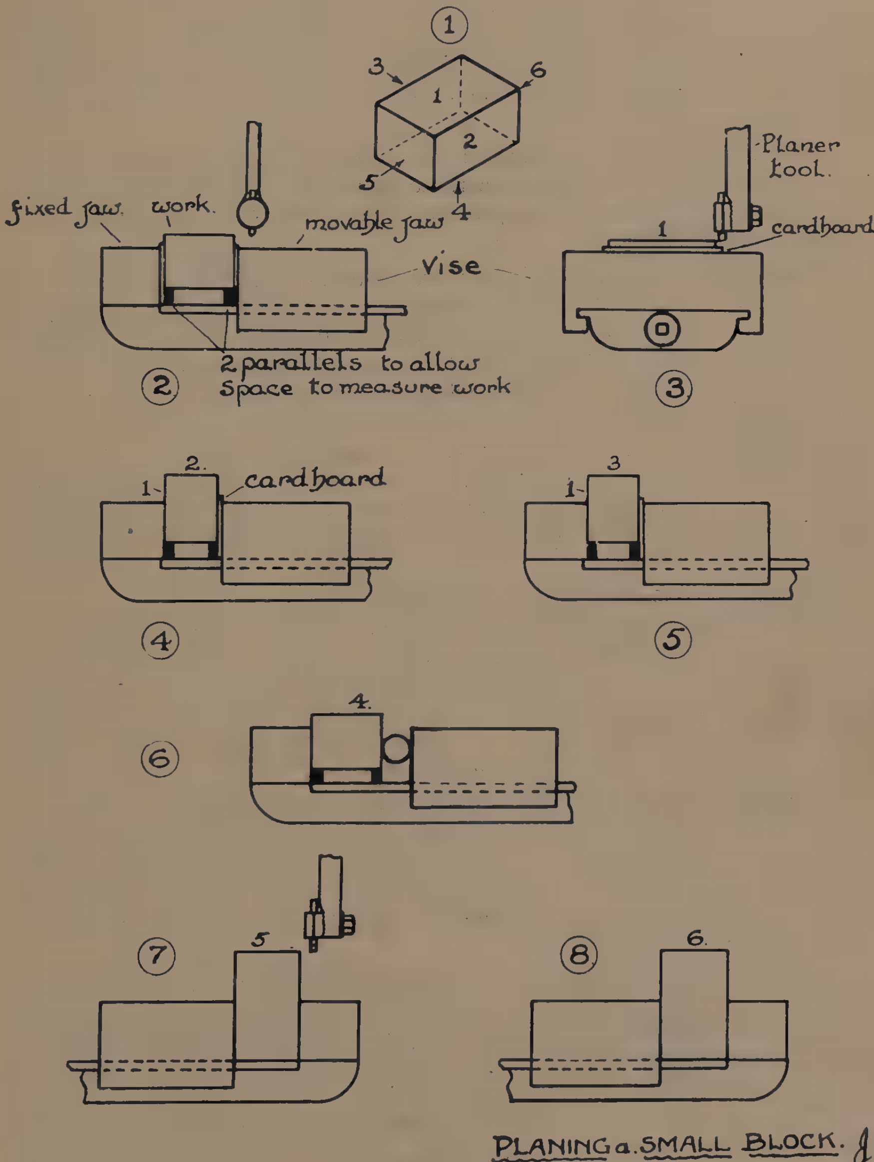
Note:—The skin of cast iron is very hard and therefore a suitable speed must be obtained; after the skin has been removed a faster cutting speed may be used.

Finish of the work. A finishing tool need not be used in the first planing exercise, therefore the finish of the work will depend upon the fineness of the feed.

To plane faces at right angles to each other. When No. (1) face has been machined it should be placed against the fixed jaw because it is the most accurate jaw being always stationary. Nothing should be placed between the face of the job and the fixed jaw face to ensure accuracy.

To prevent work lifting when being tightened in the vise, a round bar is sometimes used between the movable jaw and the work so that when pressure is applied the bar will roll against the work.

Squaring ends of the block. For a small block as illustrated in diagram (1) it is possible to square the ends by standing the block upright in the vise as in diagrams (7) and (8), but larger blocks have to be squared by the downfeed as will be illustrated later.


1
3
6
1
2
5
4
fixed jaw.
work.
movable jaw
Vise
2 parallels to allow
Space to measure work
2
Planer
tool.
1
cardboard
3
2.
1
cardboard
4
3
1
5
4.
6
5
7
6.
8
PLANING a SMALL BLOCK.

FINISH PLANING AND DOWN FEEDING ON SHAPER.

After completing the first lesson on planing detailed on page (90) the next step will be explained, taking for an illustration the planing of a flat block diagram (1) of cast iron which is too long to set up on end in the vise, to finish square the end. The end is squared by projecting it beyond the end of the vise and using the down feed of the swivel head when set in a vertical position.

Diagrams (2) and (3), page (91), show the rough planing, which leaves the surface of the metal serrated even with a fine feed. Notice that the tool bit is in front of the toolholder for heavy cutting to give rigidity to the tool.

Finish planing. Very light cuts are used for finish planing and the tool is placed at the back of the toolholder as shown in diagrams (2) and (3). It will be observed that the cutting edge of the tool is slightly behind the last point of support given by the tool post to the toolholder, so that under chip pressure the tool will spring away from the work, leaving a smooth finish.

Setting the tool for finish planing. Place a strip of paper between the tool cutting edge and the surface of the work and operate the down feed while the machine is stationary until the tool touches the paper. Allow two or three thousandths for the cut, and finish plane the surface with the finishing tool.

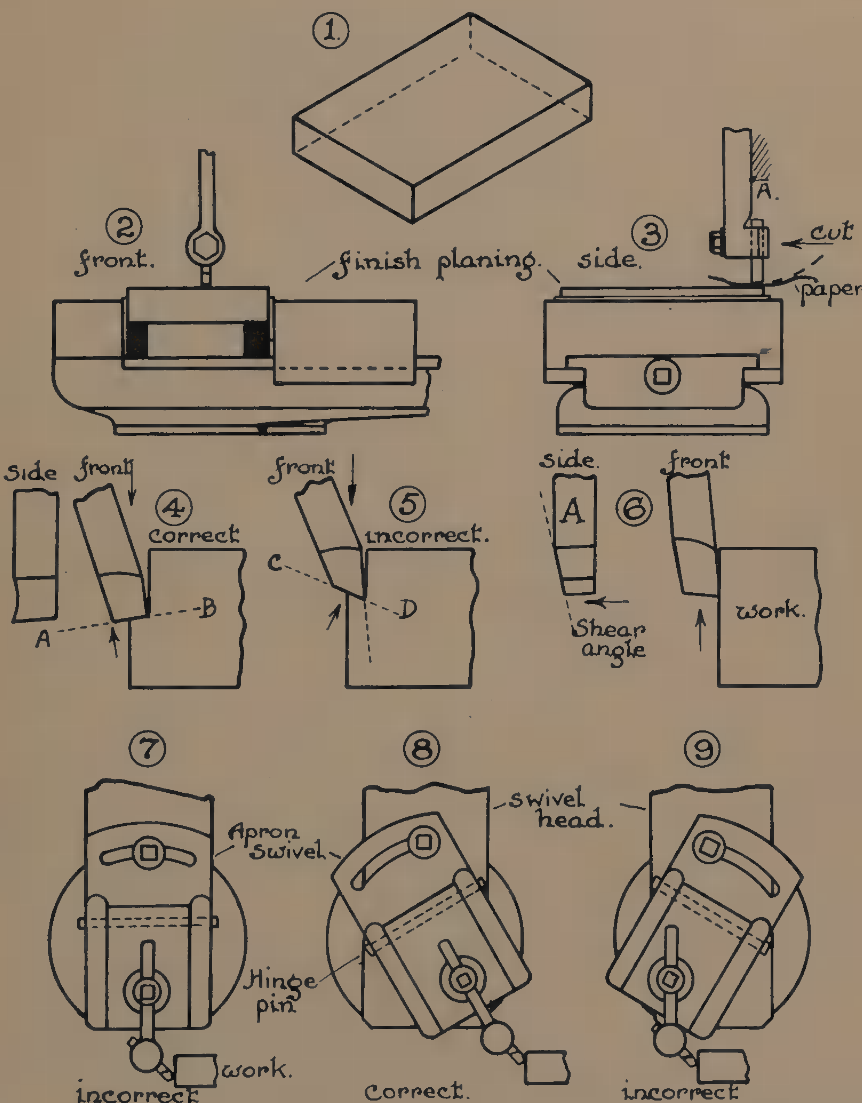
Squaring the ends with the down feed, diagrams (4) and (5). The end of the block should project slightly beyond the edge of the vise and near to the top of the vise. Select a suitable tool for cutting down, but notice particularly that the tool face A B is a least square or inclined to the surface being machined. If the tool were used as indicated by line C D the tool would be forced into the work by pressure on the side of the tool and the surface would not be square.

Finishing squaring the ends of the block. After rough squaring by down feed if the side of the tool near the work is inclined 3 or 4 degrees to it a smooth finish can be obtained by finishing the surface with an up feed as shown in diagram (6). A special side tool may be used as shown in diagram (6A), which cuts with a shear cut and leaves cast iron very smooth and square.

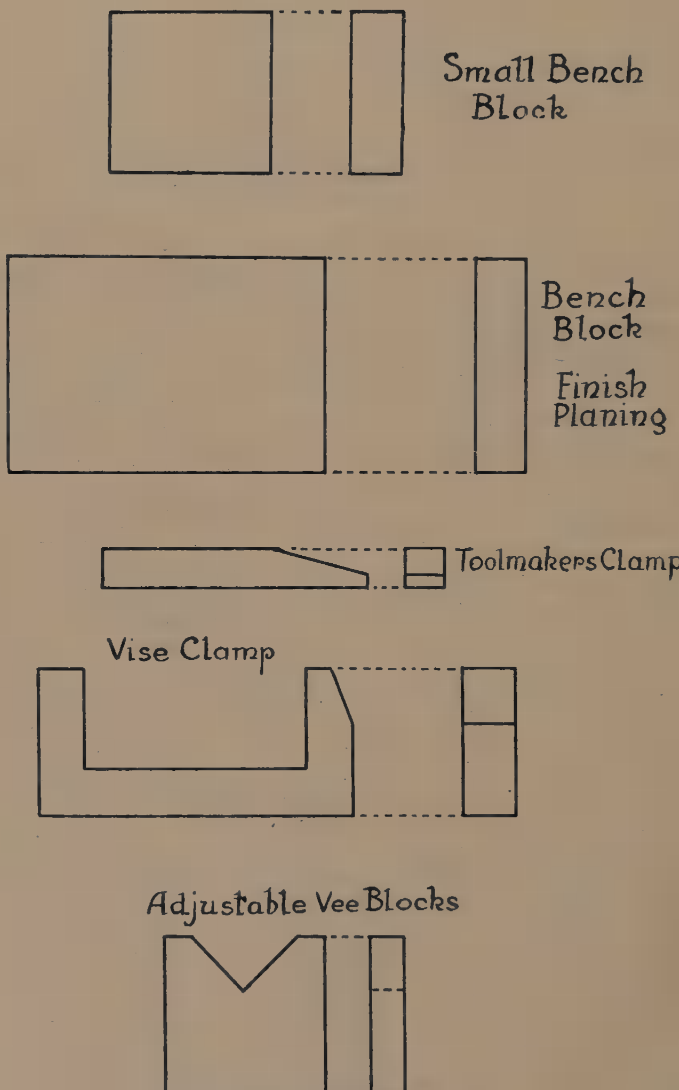
Position of apron swivel. On the return stroke the tool lifts as it comes in contact with the work, and moves in a plane at right angles to the hinge pin; this means that if the apron swivel were in a vertical position as shown in Diagram (7) the tool would scrape the surface of the work. If in position as shown in diagram (9) the tool would lift into the surface of the work and probably break the tool and spoil the work.

Diagram (8) shows the correct position for the apron swivel for the down cut illustrated. When the tool returns it lifts away from the work and will not rub.

Rule:—Always set the top of the apron in a direction away from the surface being cut.



FINISH PLANING and DOWN FEED.



Shaper Work Projects

QUESTIONS ON PLANING ON THE SHAPER.

1. What is a shaper used for?
2. Describe two types of shapers.
3. What do you understand by a 16″ shaper?
4. How are the speeds of the shaper obtained?
5. How does the rotation of the crank change into reciprocation of the ram?
6. What makes the return stroke of the ram quicker than its forward stroke?
7. How is the position of the ram changed forward or back?
8. From where, and how, does the feeding mechanism receive its movement?
9. What influence does the tool have on the direction of the feed?
10. If the feed occurs when the tool is cutting, how could you change it and why is it necessary to make the change?
11. How is the amount of the feed varied?
12. How would you change the feed from clockwise to counterclockwise?
13. How would you hold a small cast iron block in the shaper vise?
14. Name the order of operations for machining a small cast iron block.
15. How would you prevent work lifting in the vise?
16. Why are two parallels used when setting up a block in a shaper vise?
17. How is a tool used to finish plane work? How much cut is taken when finish planing?
18. How is the planing tool set for down feeding?
19. What is the best tool for finishing a vertical face?
20. How is the apron swivel placed when vertical feeding? Why?

MILLING

THE UNIVERSAL MILLING MACHINE.

The milling machine was first designed for the purpose of forming the spiral flutes in twist drills, but since that time the machine has been improved and has many other uses. Fundamentally, the machine to-day is similar to the one first developed by Mr. J. R. Brown, of the firm of Brown & Sharpe.

The work is held on the table by various devices and is fed against the revolving cutter which has usually several cutting edges, each tooth cutting away a portion of the material and producing on the work a shape similar to the form of the cutter.

The cutters are made in different forms to produce work of regular or irregular shapes, to cut grooves and keyways, tee slots, to groove taps, reamers and drills, and to cut gears, etc.

The machine is usually driven from a countershaft by belt to the speed cone and so direct to the spindle, or through gears similar to a lathe to obtain a further range of spindle speeds.

The table is fed past the rotating cutter automatically or by hand, and the rate of the feed is controlled by a feed changing mechanism which is sometimes driven independent of the spindle speeds, thus giving a great range of feeds with regard to the spindle speeds.

The table can also be fed transversely, that is, to or from the column by hand or automatically. A vertical movement can also be given to the table by hand, and on some machines by power. The table can be swivelled horizontally when required, as in fluting twist drills.

The column of the machine carries on its front slide the knee, which supports the table, and the knee is supported from the base of the machine by a telescopic screw by which it can be raised or lowered.

The index head is sometimes fastened to the table and can be geared to the screw beneath the table so that work can be fed past the rotating cutter while the work itself is being rotated at a desired rate, thus producing a spiral cut.

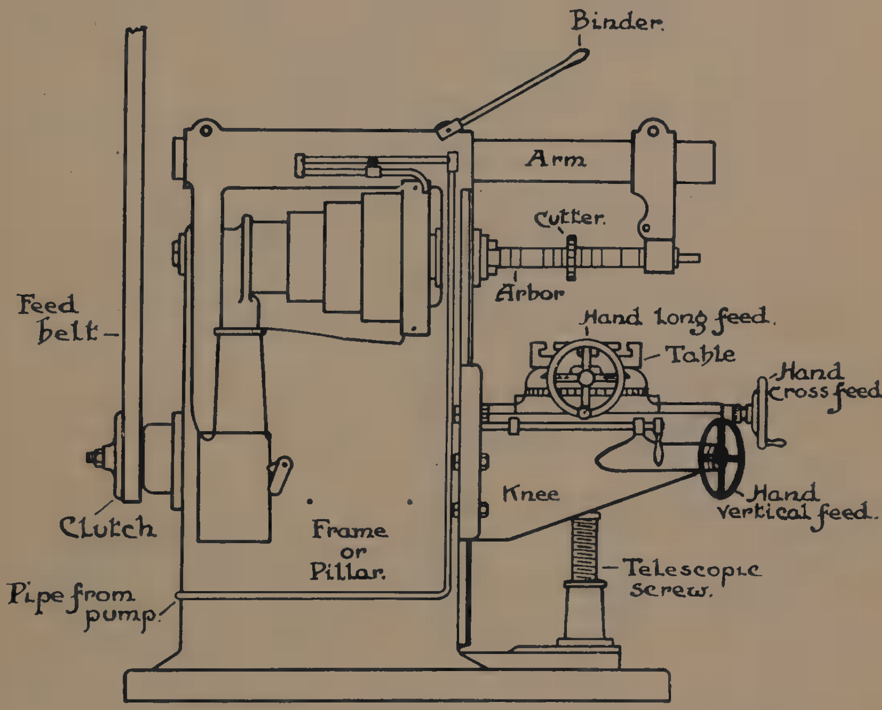
The Index head is also used for dividing work into an equal number of parts as in cutting the teeth of a gear.

A Chuck can be fastened on the index head spindle to hold work for indexing, as in squaring the head of a bolt, when the index head is swivelled in a vertical position.

The vise is often bolted to the table to hold work to be milled.

The arm can be moved in and out of the column and it carries on its outer end the outer arbor bearing support. When heavy work is being done, arm braces are used to support the arm from the knee.

The arbor fits into the Brown & Sharpe tapered hole of the spindle and receives also the support of the outer arbor bearing. The cutter is fitted to the arbor, being driven by the friction of the collars which are tightened on the cutter by a nut on the end of the arbor, or, if under great strain, the cutter can also be keyed to the arbor.



THE UNIVERSAL MILLING MACHINE

MILLING ARBOR AND CUTTERS.

Milling machine arbor. There are different styles of arbors suitable for light or heavy work. The arbor shown in Diagram (1) is the general type used, and is suitable for heavy work. It fits into the spindle of the machine with a Brown & Sharpe taper. A drawing-in bolt passes through the spindle to hold the arbor securely to the spindle. The arbor is backed out by the backing out nut shown in the diagram. The other arm bearing supports the outer end of the arbor and the arbor is provided with an inner bearing for greater arm support.

Collars of various sizes are used to accommodate the cutters, and must be kept clean and accurate to give the cutter an even support when the nut is tightened on the end of the arbor. A key is sometimes used to give greater security to the cutter when doing heavy work.

The plain milling cutter, diagram (2), cuts a plain surface parallel to its axis. Cutters over ¾″ in width have helical teeth to prevent chatter; cutters less than ¾″ have straight teeth. Diagram (3) shows a small plain cutter used for grooving, cutting keyways, etc.

Angular cutters, as shown in diagram (4), cut surfaces which are inclined to the axis of the cutter, and are made with various angles as 45°, 50°, 60°, 70°, 80°. Clearance is ground on the face and side of the cutters.

Slitting saw, as shown in diagram (5), is used to cut off stock and to slit work. An example of this may be seen in a lathe footstock.

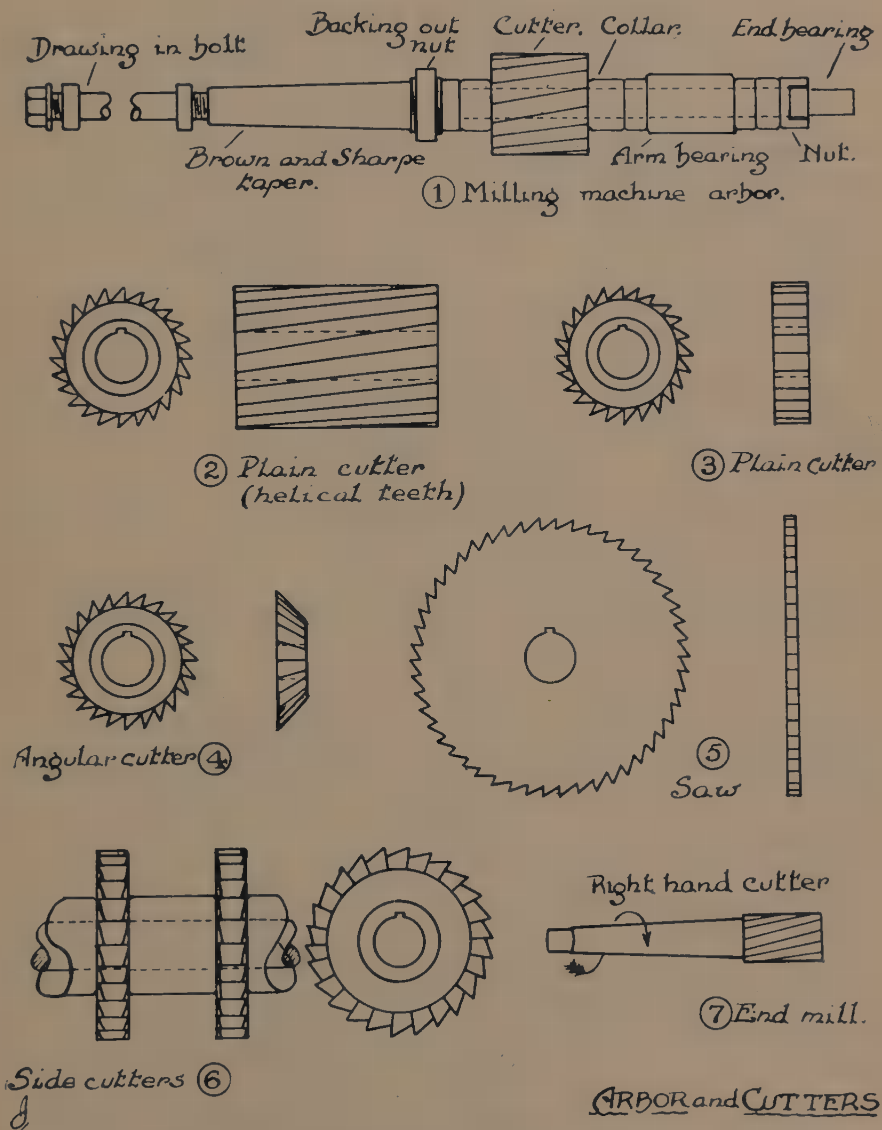
End mills, as shown in diagram (7), cut on the periphery and at the end, and are used for squaring ends to a shoulder and for slots and some keyways. End mills over ⅝″ diameter usually have spiral teeth on the periphery.

Right and left hand cutters. Milling cutters may be made right hand or left hand accordingly to the direction in which the cutter revolves to cut when observed from the back or shank end of the cutter. A left hand end mill has a right hand spiral and vice versa so that reaction from the cutting tends to tighten the cutter in the spindles.

Note:—When mounting milling cutters on the arbor great care should be exercised to see that the arbor, collars and cutting are clean. When the cutter is in operation it will be noted that the teeth do not always cut equally, that is, the periphery of the cutter runs slightly out of true.

The periphery of milling cutters are ground concentric with the hole passing through the centre, and if the cutters are turned slightly on the arbor, sometimes a better position can be found.

An attachment to grind the cutter when fastened on the arbor would guarantee even cutting on all teeth but this would be rather inconvenient when cutters are changed often.


Drawing in bolt
Backing out nut
Cutter.
Collar.
End bearing
Brown and Sharpe taper.
Arm bearing
Nut.
1 Milling machine arbor.
2 Plain cutter (helical teeth)
3 Plain cutter
Angular cutter 4
5 Saw
Side cutters 6
Right hand cutter
7 End mill.
ARBOR and CUTTERS

MILLING A PLAIN CAST IRON BLOCK.

One of the simplest operations for a beginner is to mill all the surfaces of a cast iron block. It involves the use of the vise which is bolted to the table and also the use of a plain milling cutter of sufficient length to cover the widest cut.

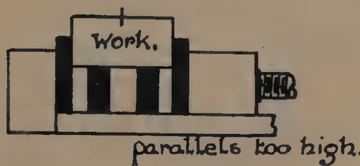
To produce surfaces that are parallel, is not quite so easy as it may first appear, and, therefore, every care should be taken in setting up the work. Cast iron, although a comparatively easy metal to cut, has a hard skin, and care should be taken to see that the casting is pickled before taking a cut. Otherwise, the milling cutter will be dulled.

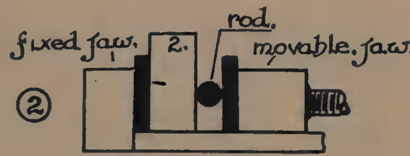
The setting up of the block is similar to the set up in a shaper vise. If the work is placed too high in the vise, as shown in diagram (1), chattering may result. Diagram (4) shows the work held low down in the vise to give rigidity. If the parallels are placed with a space between it will be possible to measure the work. The piece of round stock is placed between the vise jaw and the work as shown in diagram (2) to prevent the work from lifting from the vise seat under the pressure of the vise. A piece of cardboard may be placed between the rough side of the work and the vise jaw, as shown in diagram (3). This absorbs the irregularities of the casting and distributes the pressure evenly on the block, and also prevents the vise jaw from damage.

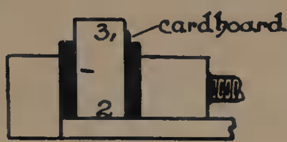
The faces of the block are milled in the order shown by the numbers in diagrams (1) to (4). It is advisable to check up the vise jaws to see that they are at right angles to the arbor after the vise has been set to the graduations marked on the base, as shown in diagram (5).

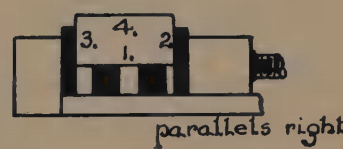
The work should be fed in the opposite direction to the rotation of the milling cutter, as shown in diagram (7), for two reasons. If the work is fed as shown in diagram (6), the cutter will tend to climb on the work and thus probably ruin the cutter. If the cutter comes first in contact with the hard skin it will be dulled. It should always cut under the hard skin as shown in diagram (7), and thus pry it off.

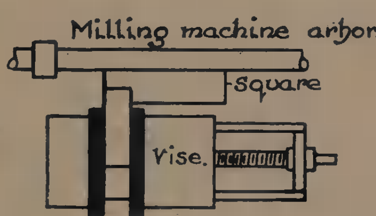
In squaring the ends of the block by the use of the vertical feed, the work should be fed upwards so that the cutter will press it against the seat of the vise, as in diagram (8). If the feed is operated downwards, the cutter will tend to lift the block from the vise seat.

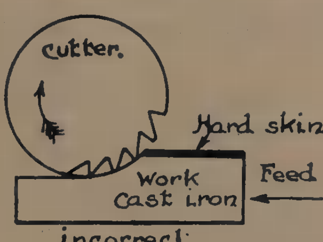
1

Work.
parallels too high.

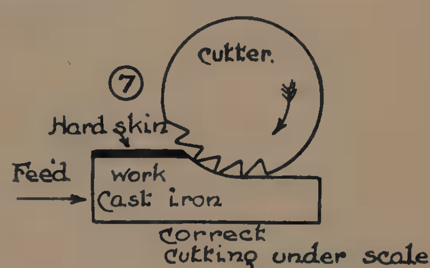
2

rod.
fixed jaw.
2.
movable. jaw.

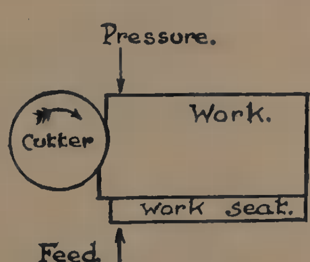
3

3,
cardboard
2

4

4.
3.
2
1.
parallels right

5

Milling machine arbor.
Square
Vise.

6

cutter.
Hard skin
Work
Cast iron
Feed
incorrect

7

cutter.
Hard skin
Feed
Work
Cast iron
correct
cutting under scale.

8

Pressure.
Work.
Cutter
Work seat.
Feed

J.

MILLING A VEE BLOCK.

The cast iron block should first be machined on all sides and ends, as explained in the milling of a plain block.

When setting other cutters to cut from a finished surface, it is advisable to use a strip of paper .003″ in thickness and rotate the cutter while the work is raised by the vertical feed until the cutter pushes the paper from the surface of the work, as shown in diagram (1). Allow for the thickness of the paper in adjusting the cutting depth.

Diagram (2) shows the method of squaring the ends of the block by operation of the vertical feed.

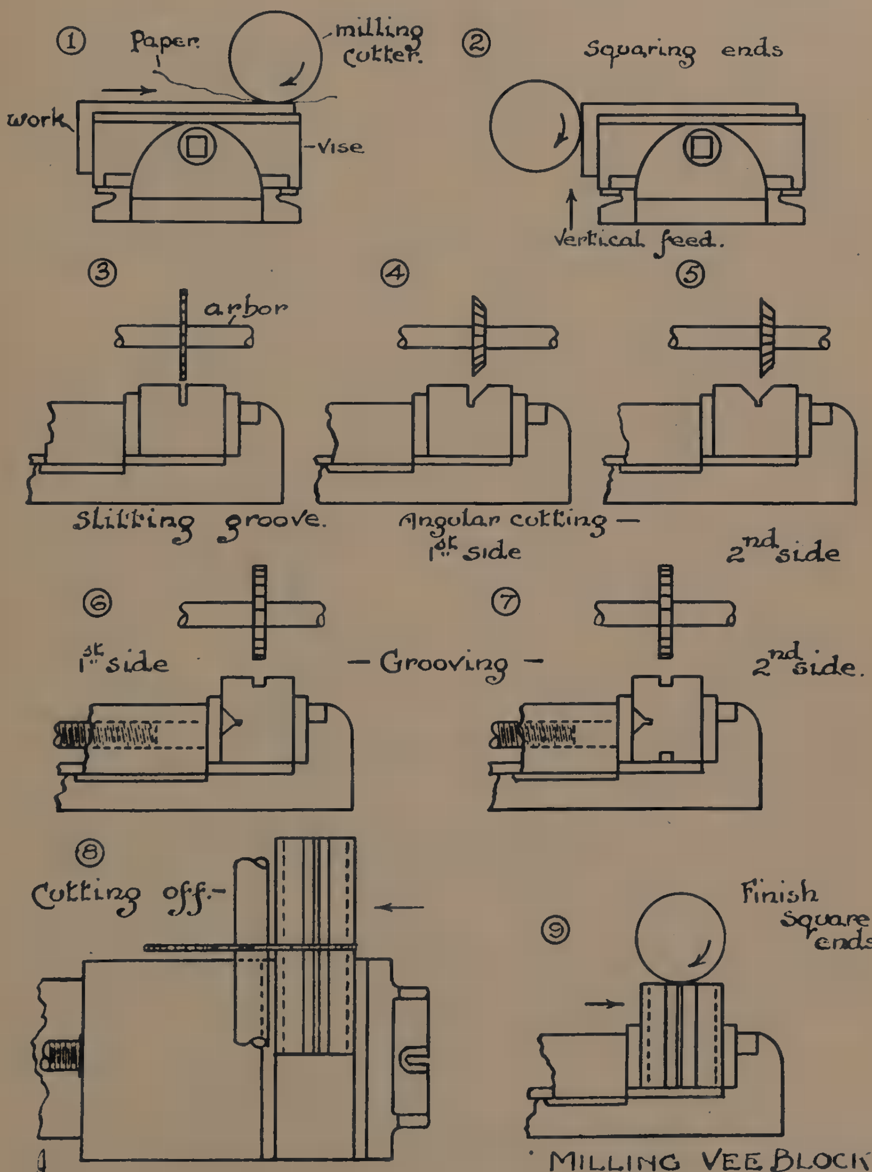
Diagram (3) shows a small groove cut in the block previous to cutting the angular surfaces of the vee. This will simplify the work of angular cutting for a beginner.

Diagrams (4) and (5) show the position of the cutter and the work for cutting the angles. It is necessary to set the vertical face of the cutter exactly central with the block before starting the cut, and to adjust by the vertical feed until the cutter cuts to the correct depth, which can be noted by a scribed line on the upper surface of the block. Use the automatic long feed to finish the cut. Then reverse the block, and if the cutter was correctly set central as in diagram (4), the second cut, as shown in Diagram (5), will be central also.

Diagrams (6) and (7) show the grooving operation. Care must also be taken here to set the cutter central with the face of the block. This may be accomplished by using a rule against the side of the cutter, measuring the distance to the edge of the block, which should be half the width of the block minus half the width of the cutter.

Diagram (8) shows the cutting off operation by means of a slitting saw of such a diameter that the block will be cut through without the arbor coming in contact with the surface of the work, when fed by automatic long feed.

Diagram (9) shows the ends being finish squared. It is necessary to see that the block stands vertically in the vise by use of a square set on the vise seat. When the face milling cutter has been set to cut to the scribed line, the cut can be finished by the automatic long feed.


1
Paper
milling cutter.
work
Vise
2
Squaring ends
Vertical feed.
3
arbor
Slitting groove.
4
Angular cutting —
1st side
5
2nd side
6
1st side
— Grooving —
7
2nd side.
8
Cutting off.-
9
Finish square ends
MILLING VEE BLOCK

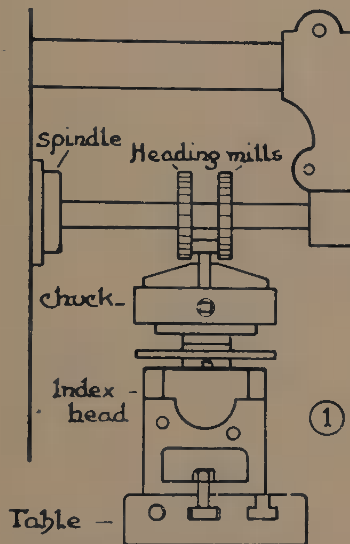
MILLING—RAPID INDEXING.

Rapid indexing is the simplest form of indexing work on the milling machine. Other methods are known as plain and differential. The Index Head is bolted to the machine table and work may be held in a chuck screwed to the Index Head spindle, or other work may be supported by the centres of the Index Head and Footstock. The dog on the work must be clamped securely to the face plate to prevent backlash, which would cause inaccurate division of the work. For rapid indexing it is necessary to disengage the worm which is turned by the crank when used for plain and differential indexing. The spindle of the head is turned by hand and the divisions (usually 24) are used on the rapid index plate, being locked in position by the pin P, diagram (3).

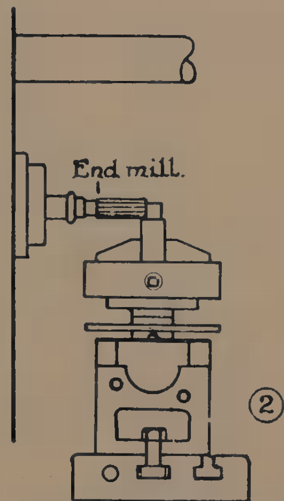
To mill bolt head. The side milling cutters of the same diameter are set up on the arbor with a spacing collar between them the correct size of the distance across the flats of the bolt head. The work is held in the chuck as shown in diagram (1). It is advisable for a beginner to check up the setting of the cutters and work by testing with a piece of scrap to prevent spoiling the bolt. Set cutters central, take a light cut to see if the cutters cut to the size required across the flats and cut centrally with the work. If the size is too small, increase the spacing by the addition of paper or brass washers. If too large, use a smaller collar, or reduce the collar being used. Now Index the work one-half way round and take another cut. If the cut coincides with the first cut, the work is central. If incorrect, measure the thickness now cut, and subtract it from the previous thickness and feed the work one-half the difference away from the cutter.

Squaring to a sharp shoulder with an end mill—Diagram (2). Set the work against the rotating cutter until a piece of paper is moved from between them, then set the cut an amount equal to one-half the difference of the diameter of the stock and the size across the flats required. It is advisable when milling the first piece to take two opposite roughing cuts, then measure the distance across the flats and adjust the work one-half the difference to finish to the exact size.

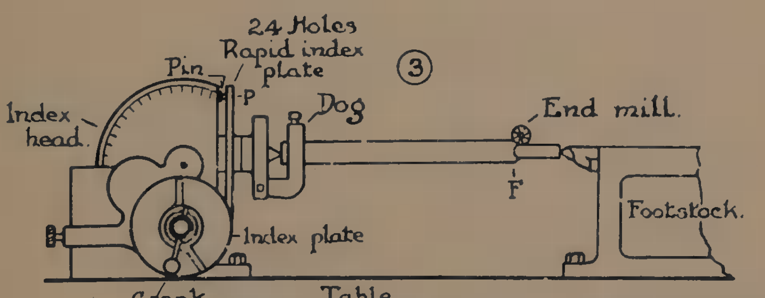
To mill the end of a shaft with curved shoulders. The work is mounted on centres as shown in diagram (3), the indexing is done as previously described. It is necessary to set the dog to trip the feed at F. so that all cuts terminate at the same distance from the end of the work. Take trial cuts and measure across the flats. If the work is large, adjust by elevating the work by the vertical feed one-half the difference and mill the sides in order.



Milling Bolt Head.

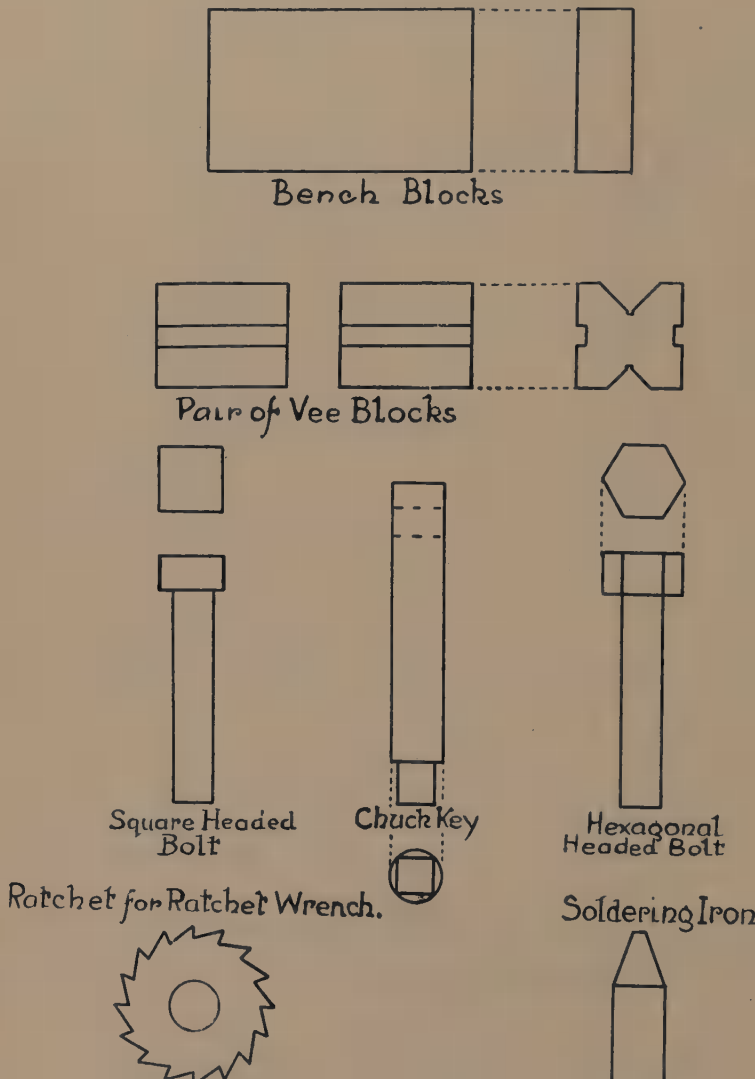


Milling square Head.



Milling shaft square - curved shoulders.

RAPID INDEXING.



Milling Projects

QUESTIONS ON MILLING.

1. Name six main parts of a Universal milling machine and describe the function of each.
2. What are various parts of the milling machine arbor when the cutter is in place?
3. What method of operation would you adopt to mill a plain block on all sides when held in a vise fastened to the table?
4. How should a cutter be set to cut to correct depth?
5. How should a cutter be set to cut a groove central in a block?
6. How would you mount a cutter on an arbor
   (a) for light work?
   (b) for heavy work?
7. What method would you use to mill a square and hexagonal shank on round stock?

GRINDING

THE GRINDSTONE.

Grinding to-day is a very important operation; it has developed in a comparatively short time from a simple operation involving the use of an ordinary grindstone to intricate work in the finishing of machine products requiring the use of elaborate precision grinding machines. Grinding is an operation which is used in many industries so that a knowledge of this important work is necessary. The beginner should follow up the work shown here by a study of abrasives and the manufacture and selection of grindstones.

The grindstone is made from abrasive grains with sharp cutting edges bonded together and baked to form wheels of various shapes. The size of the grains used decides whether the wheel is a coarse or a fine wheel. The grains are screened as shown in diagram (1), which represents a 10 grain screen or 10 meshes per linear inch. The grains which pass through such a screen are shown in diagram (2).

The section of a grinding wheel is shown in diagram (3). It illustrates the idea that the grains are held together by a bond, but the wheel has a porous structure. When the outer grains lose their sharp cutting edges, the extra pressure required to cut the metal due to their dullness should be sufficient to overcome the holding power of the bond and break the dull grains free, thus producing beneath a new layer of sharp cutting grains.

Diagram (4) shows metal ground by a dull wheel, the metal particles are round showing that they have been rubbed off, thus generating by friction a great amount of heat.

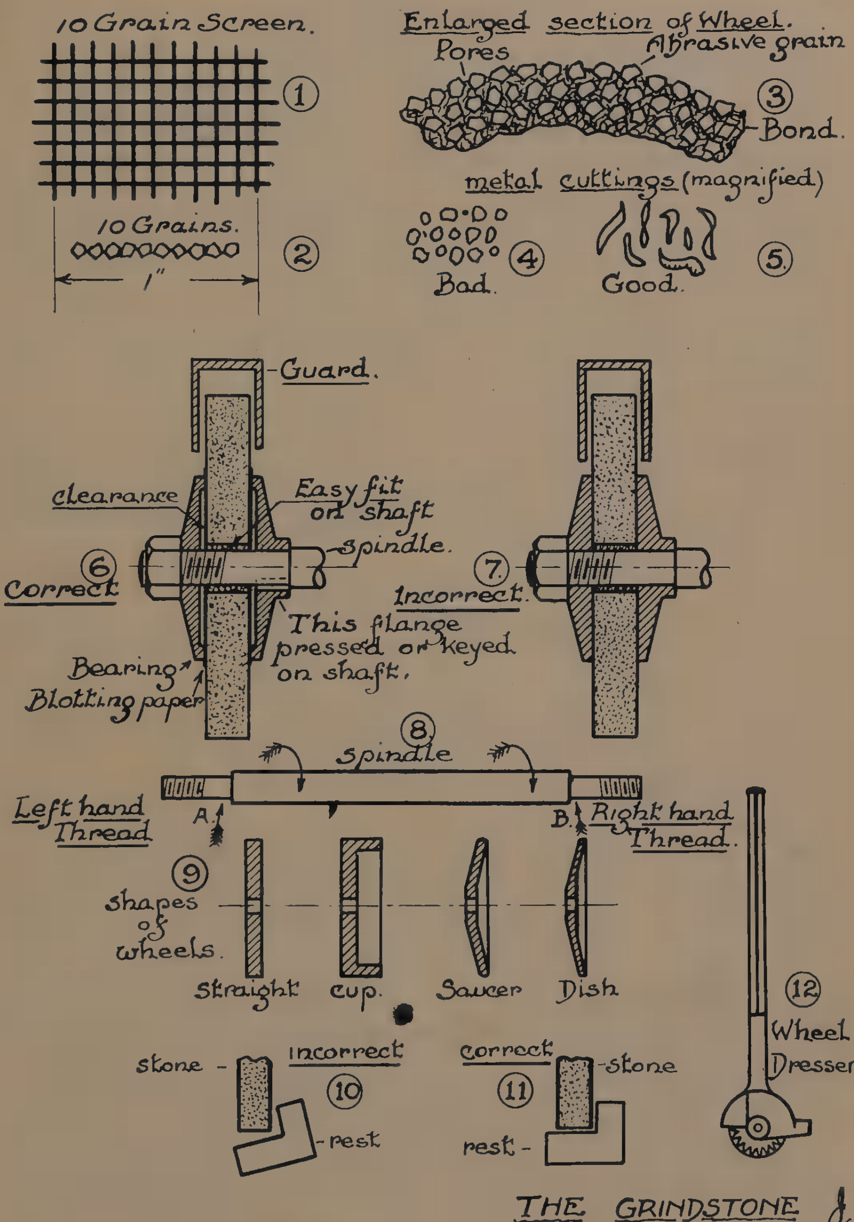
Diagram (5) shows the cuttings from a free cutting wheel. The grindstone is really a cutting tool with thousands of cutting edges. The cuttings when magnified prove this, because they are quite similar to the cuttings taken from a lathe.

Mounting a wheel on a spindle, diagrams (6) and (7). It is very important that a wheel should be correctly mounted on the grinder spindle as incorrect mounting has been the cause of wheels breaking and serious accidents resulting from the flying parts of the stone. The wheel guard of course is to prevent the broken parts from flying away and has saved many lives.

Eye protection. The flying grains of abrasive and small particles of metal form another frequent source of danger to any operator. Goggles should be worn and it is advisable for each operator to have his own always at hand as the use of a pair of goggles used by other helps in the transfer of many serious diseases. Sometimes a glass screen fastened to the grinder is effective.

Diagram (8) shows how both nuts are tightened on the spindle when rotating in direction of arrows. The nuts A and B each tightening the flanges against the shoulders of the spindle.

Diagram (9) shows some common shapes of wheels used.



Note:—The dangerous position of rest in diagram (10) and the safe correct position in diagram (11).

The wheel dresser. Diagram (12) is used to break away worn out abrasive grains, thus making the wheel cut sharp and clean. A diamond dresser is used for fine precision work.

TOOL GRINDING.

Most cutting tools are simply wedges entering the material by the sharpness of their edges, and forcing it open or separating it by the gradual increased thickness it presents with its wedgelike form. A thin-edged or sharp-angled wedge tool cuts freely because it generates less friction than a thick-wedged tool. A common axe is a simple example of the wedge principle and everyone is familiar with the tremendous power of an ordinary wedge. If a wood chisel is forced into a piece of wood as shown in Diagram (2) the chisel will tend to follow the direction of the side nearest to the material. As it penetrates deeper it will require more power to push it, owing to the increased amount of material it is removing. If the chisel were held in a vertical position the material would be pushed or scraped off and the edge would rapidly become rounded and dull.

The planer or shaper tool shown in diagram (3) is a wedge-like tool with a large angle because the material cut is very much harder than wood. The angle of clearance need only be sufficient to prevent friction between it and the work as it passes over it. A large wedge angle is given to a metal tool for the following reasons:—

(1) For strength.

(2) To dissipate the heat caused by the friction in cutting.

The chip, as it is removed, presses hard against the tool face, so that if the tool is curved as shown in diagram (4) the passage of the chip is made easy.

The lathe tool shown in diagram (4) shows a wedge entering cylindrical material, the roundness of the material giving greater clearance because it moves away from the tool. The tool naturally tends to penetrate along the dotted line shown, which should be tangent to the surface of the turned part of the work.

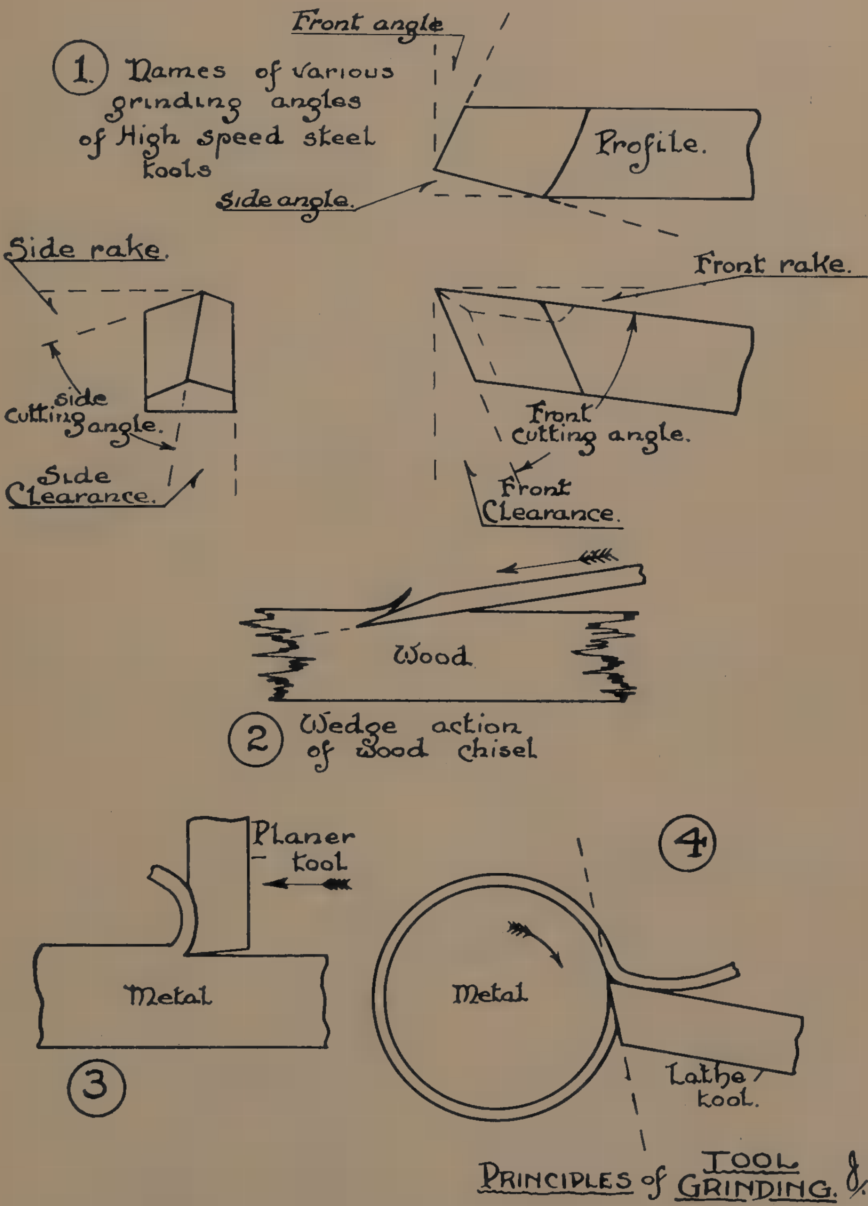
Diagram (1) shows the Plan, Elevation, and End Elevation of a High Speed steel tool bit. The names of the various possible grinding angles are shown in the position in which the tool is used in the tool holder.

The profile of the tool is the shape of the tool as it appears when looking at it from above, while it is in operation. The profile has a great influence on the efficiency of the tool under various conditions as will be seen later.

Front cutting angle is the wedge shape which penetrates the stock when cutting from the front of the tool. A thin edged tool cuts easily because it generates less friction than a thicker edged tool, but the wedge angle must be sufficiently large to stand up to the work it has to do.

Side cutting angle is that which penetrates the stock when cutting on its side or towards the headstock of the lathe.

Front rake reduces chip pressure as the chip leaves the work from the front. More rake increases the tendency to penetrate the material.



Side rake reduces chip pressure as the chip leaves the work from the side.

Front clearance governs the wedge angle of the tool from the front.

Side clearance governs the wedge angle of the tool from the side.

METHODS OF POLISHING.

Polishing has been defined as the operation of making a metal "smooth and glossy". In practice the operation is divided into three general divisions, grinding, polishing and buffing. The function of grinding is to remove material and leave the work with regular serrations. Polishing reduces the serrations so that they can be scarcely seen and buffing produces a grainless finish, free from noticeable scratches.

Abrasives used. The abrasives used for "roughing" usually run from No. 20 to No. 90. For dry fining, from No. 90 to No· 120. For finishing, from No. 150 to the fine flours. For roughing and dry fining the polishing wheel should be used dry. For finishing, the wheels are first worn down a little and then tallow abrasive cake as shown in diagram (4) or beeswax is applied to the wheel to bring up the finish.

Polishing wheels. The wood wheel, diagram (1), is one of the oldest types of polishing wheels. It is made up of thin pieces of wood glued together with the grain in opposite directions. The periphery is covered with a strip of oak tanned sole leather fastened to the wood with wooden pegs. *A Felt covered wheel* diagram (2) is similarly used, its cushion action being more suitable for rounded surfaces.

Bull neck wheels, diagram (3), are solid pieces of bull neck leather, very tough and resilient and are adapted for polishing stove trimmings and similar work.

Canvas wheels are made up of discs of heavy canvas or duck, sewed, glued or cemented together. Sewed wheels are the more resilient, those made with glue or cement are stiffer. Canvas wheels are used for polishing metals with irregular surfaces as shown in diagram (5).

The cotton wheel, diagram (6), a "mop" consists of free strands of cotton and is used for the final finishing of work to make it glossy. The fine abrasive is applied to the wheel while rotating in the form of a cake (diagram 4) made up of tallow and abrasive, the tallow tending to hold the abrasive on the rotating wheel giving the work a "greasing" finish.

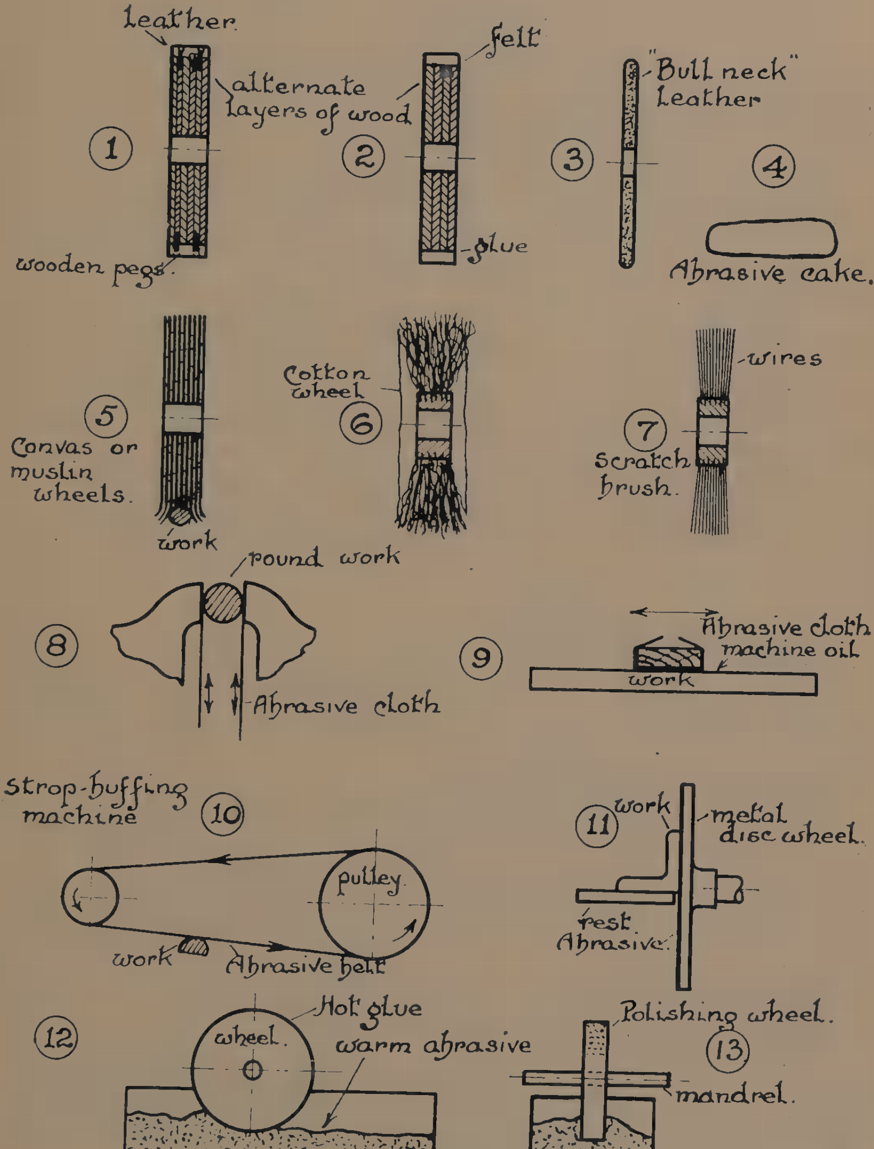
The scratch brush, diagram (7), is made up of wire made of steel or brass as required, and is generally used to scratch off the oxides from metal and give to it the particular finish known as the "Scratch brush finish". It is not properly considered a polishing operation and no abrasive is used.

Abrasive cloth. Hand polishing is often carried out with strips of abrasive cloth worked up and down by hand as shown in diagrams (8) and (9).

Polishing belt, diagram (10). This method is very satisfactory for irregular work.

Disc polishing or grinding is illustrated in diagram (11) and is often used for producing a flat regular finish on work.

Setting up wheels. To set up or cover a polishing wheel with abrasive grain, a high quality of glue is essential and should be carefully employed, the abrasive should be warm and the wheel rolled into it as shown in diagrams (12) and (13).



METHODS of POLISHING. J

SHOP MATHEMATICS

MATHEMATICS.

Laying out lines on metal at right angles. Laying out lines on metal may be simplified by a knowledge of geometry. Many problems may be met with in laying out work and the quickest and most accurate method of laying out should be applied.

The dotted line in each problem represents the line which was to be constructed.

Problem (1). To erect a perpendicular to a given straight line A B at a given point in it X.

Solution. Mark off two points C and D at equal distances from X. From C and D as centres with any radius greater than C X draw arcs cutting at O. Join O X which is perpendicular to A B.

Problem (2). To draw a perpendicular line to a given straight line A B from a given point X outside the line.

Solution. When X is not near the end of the line: from X as centre with sufficient radius, draw an arc cutting A B at P and Q. From P and Q as centres with any radius greater than half P Q describe arcs cutting at Y. Join X Y cutting A B at O. Then X O is perpendicular to A B

Problem (3). To draw a perpedicular to a given straight line A B from a given point X outside it, near one end of the line.

Solution. Take any two points D and E in A B. From D as centre, radius D X, draw an arc; and from E as centre, with radius E X draw a second arc, cutting the first at X and Y. Join X Y, cutting A B at O. Then X O is perpendicular to A B.

Problem (4). To draw a perpendicular to a given straight line A B at a given point X near to the end of A B.

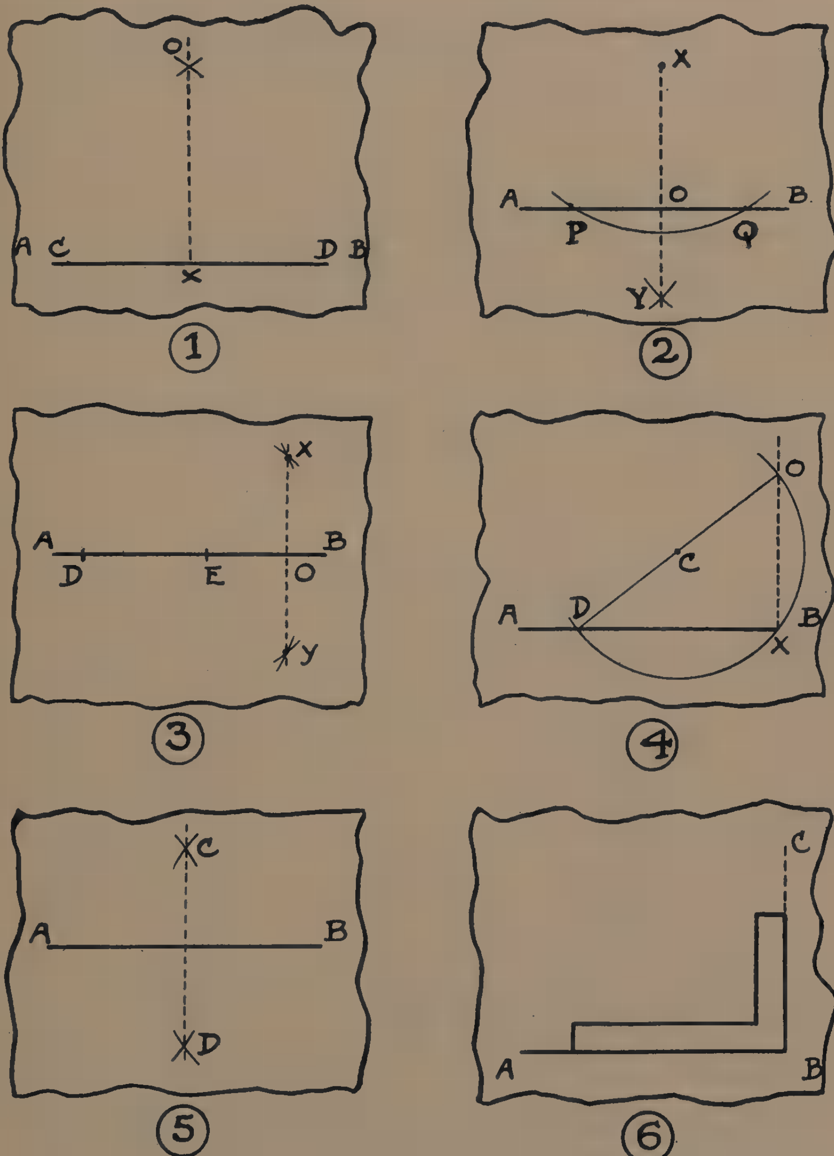
Solution. Take any point C outside A B. From C as centre, with radius C X draw a circle cutting A B at D . Join D C and produce it to meet the circumference at O. Join O X. Then O X is perpendicular to A B.

Problem (5). To bisect a given straight line A B by a line C D at right angles to A B.

Solution. With A as centre and a radius A C greater than half A B describe an arc on each side of the line. Similarly with B as centre and radius A C describe arcs on each side of the line. Join the points C and D where the arcs intersect, then C D bisects A B at right angles.

Problem (6) to draw a line C B at right angles to a given straight line A B, at a given point B.

Square method Diagram (6). A flat square is placed with one side on A B and held steady in position while the line C B is drawn at right angles to A B.



DRAWING LINES at RIGHT ANGLES

DRAWING LINES PARALLEL AND AT ANGLES.

1. To draw a line parallel to a given line at a given distance, take any points as C D as centres on the line A B and draw arcs with the given distance as a radius. The line E F tangent to these arcs is the required parallel.

2. Through a given point to draw a straight line parallel to another straight line. Let P be the given point, and A B the given straight line. With P as centre and any suitable radius, describe an arc C D intersecting A B at D. With D as centre and the same radius, describe the arc P E. With D as centre and a radius equal to the chord of the arc P E describe an arc intersecting C D in C. A straight line drawn through P and C will be parallel to A B.

3. To bisect an angle. With the vertex of the angle A as centre and any radius draw an arc D E, with D and E as centres and a radius greater than one half D E, draw arcs intersecting at F. The line A F bisects the angle B A C.

4. To draw an angle on a line equal to a given angle F G H. With G as a centre and any radius, draw an arc K L. With point A on the given line the vertex of the desired angle as centre and with the same radius draw the arc D E. With D as centre and a radius equal to the distance K L strike an arc intersecting D E and draw the line A C through E. Then angle B A C equals the angle F G H.

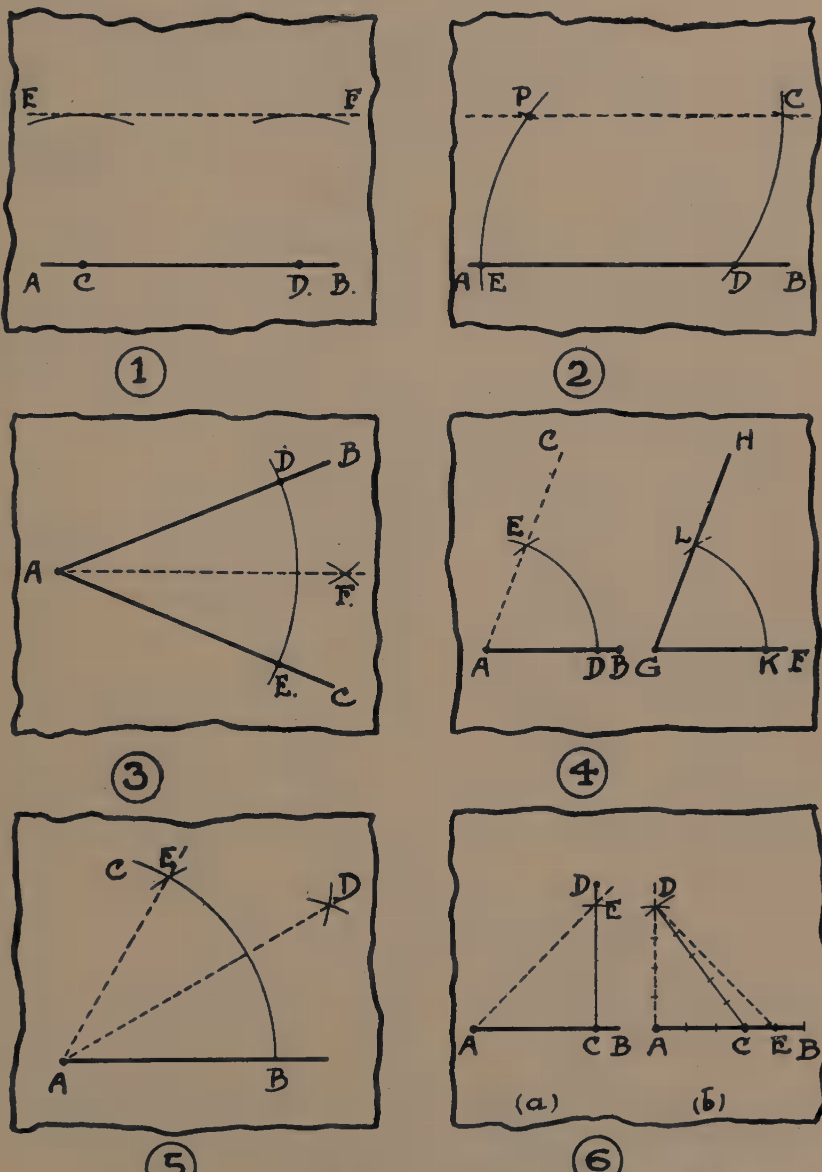
5. To lay out a 60° angle. With A as a centre and any radius, draw the arc B C. With B as a centre and A B as a radius draw an arc intersecting B C at E. Then angle E A B is 60°.

To obtain a 30° angle. Bisect the angle E A B as shown in diagram (3). Draw line A D. Then angle B A D is 30°. Diagram (5).

6. To draw a 45° angle. From a point A on the line A B lay off any distance A C. Erect a perpendicular D C and lay off distance C E equal to A C. Draw A. Then the angle E A C is 45°. Diagram (6a).

To lay out a right angle. On a line A B mark off A C any 3 units of length. From A describe an arc with 4 units of length as radius. From C with 5 units of length as radius describe an arc intersecting the first arc at D, then angle C A D is a right angle. Diagram (6b).

To obtain a 45° angle, method (2). In diagram (6)B, mark off 4 units of length from A to E. Join D E. Then the angle D E A is 45°.



LINES PARALLEL and ANGLES. J.

CUTTING SPEED, DEPTH OF CUT AND FEED.

Experiment (1). Diagram (1). Wrap a strip of paper around any cylinder and cut the paper equal to the circumference. Stretch out the paper, measure the diameter of the cylinder and the length of the paper strip, and you will find that the circumference of the circle is $3\frac{1}{7}$ times the diameter.

That is, the circumference called $C=3\frac{1}{7}$ x Diameter or $\frac{22}{7}$ x D. This relation is represented by the Greek symbol π (pronounced "Pi.") so that $C=\pi D$.

To be more exact $C=3.1416 \times D$.

Problems worked out in diagrams (2) and (3).

Experiment (2). A cylindrical piece of stock is held in the chuck of a lathe, wind string around the bar of round stock as shown in diagrams (4) and (5). Now if the string is unwound it will be observed that:—In 19 revolutions on No. 4 the string is unwound.

In 38 revolutions on No. 5 the string is unwound.

In Job 6 the tool cuts $\frac{1}{8}$ deep and has $\frac{1}{8}$ feed.

In Job 7 the tool cuts $\frac{1}{16}$ deep and has $\frac{1}{16}$ feed.

So that the removal of the string in (4) and (5) is similar approximately to the removal of metal in (6) and (7). It will be observed therefore that Job (6) has the metal removed in half the time that Job (7) has, and the material removed from (6) is twice the amount of the material removed from (7).

Cutting speed is expressed in feet per minute. It is the length of metal in feet passing the stationary tool in one minute. With stock 1″ diameter as in diagram (3).

In 1 revolution $3\frac{1}{7} \times 1$ (inches) pass the tool point in 1 minute, in 280 rev. per min. $3\frac{1}{7} \times 1 \times 280$ (inches) pass the tool pt. in 1 minute.

Now bring this to feet by dividing by 12, that is $\frac{3\frac{1}{7} \times 1 \times 280}{12}$ (feet) pass the tool point in 1 minute.

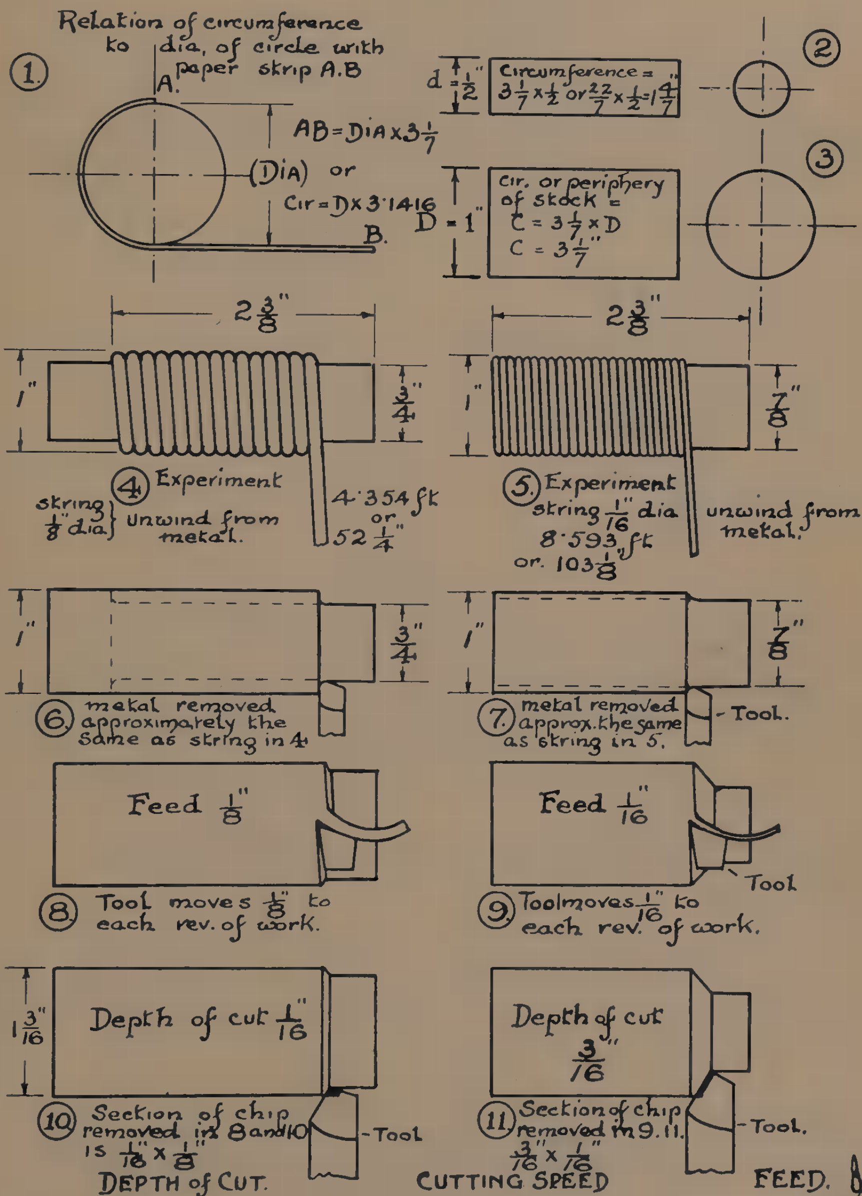
For general purposes $\frac{3\frac{1}{7}}{12}$ is roughly $\frac{1}{4}$

so that $\frac{1 \times 1 \times \overset{70}{\cancel{280}}}{\cancel{4}}$ feet = 70 feet per minute.

Exact method

$$\text{cutting speed (C.S.)} = \frac{3.1416 \times D \times R.\,P.\,M.}{12}$$

$$\text{Revolutions per minute (R. P. M.)} = \frac{CS \times 12}{3.1416 \times D}$$


Relation of circumference to dia. of circle with paper strip A.B
A.
B.
AB = Dia x 3 1/7
(Dia) or
Cir = D x 3·1416
d = 1/2"
Circumference = 3 1/7 x 1/2 or 22/7 x 1/2 = 1 4/7"
D = 1"
Cir. or periphery of stock = C = 3 1/7 x D
C = 3 1/7"
2 3/8"
1"
3/4"
7/8"
Experiment
string 1/8" dia
Unwind from metal.
4·354 ft or 52 1/4"
Experiment
string 1/16" dia
8·593 ft or 103 1/8"
unwind from metal.
metal removed approximately the same as string in 4
metal removed approx. the same as string in 5.
Tool.
Feed 1/8"
Feed 1/16"
Tool moves 1/8" to each rev. of work.
Toolmoves 1/16" to each rev. of work.
Tool
1 3/16"
Depth of cut 1/16"
Depth of cut 3/16"
Section of chip removed in 8 and 10 is 1/16" x 1/8"
Section of chip removed in 9.11. 3/16" x 1/16"
Tool
Tool.
DEPTH of CUT.
CUTTING SPEED
FEED.

Approximate method

$$C.S. = \tfrac{1}{4} \times D \times R.P.M.$$

$$\text{or } R.P.M. = \frac{C.S.}{\tfrac{1}{4} \times D}$$

Example:—What number of R.P.M. is necessary for a piece of machine steel 2½ dia., to give a cutting speed of 70 feet per minute. (High speed steel tool used).

Exact method

$$R.P.M. = \frac{C.\ S. \times 12}{3.1416 \times D}$$

$$R.P.M. = \frac{70 \times 12}{3.1416 \times 2.5}$$

$$R.P.M. = 107$$

Approximate method

$$R.P.M. = \frac{C.\ S.}{\tfrac{1}{4} \times dia.}$$

$$R.P.M. = \frac{70}{\tfrac{1}{4} \times 2\tfrac{1}{2}}$$

$$R.P.M. = \frac{\overset{14}{\cancel{70}} \times 4 \times 2}{1 \times \cancel{5}}$$

$$R.P.M. = 112$$

Feed is the amount the tool advances parallel to the axis of the work for each revolution of the work, as shown in (8) and (9).

Depth of cut is the amount the tool enters the work at right angles to its axis. In diagram (6) the tool is shown reducing the diameter of the stock from 1″ to ¾″ therefore the depth of cut is one half the difference of these diameters or ⅛″. In diagram (7) the depth of cut is $\frac{1}{16}$″.

Diagram (10) shows a $\frac{1}{16}$″ depth of cut with a coarse feed ⅛″, and diagram (11) shows a $\frac{3}{16}$″ depth of cut with a $\frac{1}{16}$″ feed.

AREA, VOLUME AND WEIGHT OF METAL.

It is necessary at times to estimate the weight of metals from drawings provided in order to give a price on the cost of the work. To do this it is necessary to know how to calculate area and volume. The problem following gives a simple idea of the elements of this work.

Diagram (3) on page 123 shows a rectangle 1¼″ x 1″ divided into ¼″ squares. If the squares are counted, the rectangle will be found to contain 4 rows of 5 squares each—or 20 squares; or 5 rows of 4 squares each or 20 squares.

To find the area of a rectangle multiply the length by the width.

Example: Diagram (3) 1″ x 1¼″=1¼ square inches.

To find the area of a circle. Take a circular piece of paper and cut it out into divisions as shown in diagram (4). If one segment is cut in two, it will fill up each end and make an approximate rectangle A B C D, which is equal in area to the circle.

The area of a rectangle=length x width.

The length, a d=½ the circumference of the circle.

The width, a b=the radius of the circle, so that,

The area of a circle=½ circumference x radius.

When A=the area of a circle, diagram (4) shows how the formula $A = \pi R^2$ is obtained when $\pi = 3\frac{1}{7}$ and R=the radius of the circle.

To calculate the area of a circle having a diameter of 4″:

Method (1).

$$\text{Area of Circle} \begin{cases} = \frac{1}{2} \text{ cir, x radius} \\ \dfrac{3\frac{1}{7} \times 4 \times 2}{2} \\ = \dfrac{22 \times 4 \times \cancel{2}}{7 \quad \cancel{2}} = \dfrac{88}{7} \\ 12\frac{4}{7} \text{ square inches.} \end{cases}$$

Method (2).

$$\text{Area of Circle} \begin{cases} = \pi R^2 \\ = 3\frac{1}{7} \times R \times R \\ = \dfrac{22 \times 2 \times 2}{7} = \dfrac{88}{7} \\ = 12\frac{4}{7} \text{ square inches.} \end{cases}$$

To find the volume of a rectangular prism.

Example—Diagram (6).

Volume of a Prism=Area of end x height.
" " " =Length x width x height.
" " " =⅞ x ½ x 1¼.
" " " =⅞ x ½ x5⁄4=35⁄64.
" " " =.546 cubic inches.

To find the volume of a cylinder.

Example—Diagram (7).

Volume of a cylinder=Area of end x height.

" " " $=\pi R^2$ x height.

" " " $=\frac{22}{7} \times \frac{7}{16} \times \frac{7}{16} \times 1\frac{3}{8}$

" " " $=\frac{22}{7} \times \frac{7}{16} \times \frac{7}{16} \times 1\frac{1}{8} = \frac{847}{1024}$

" " " =.827 Cubic inches.

To find the weight of metal. (1) If the job shown in Diagram (6) is made of cast iron, what will its weight be?

Note: Cast iron weighs 0.26 *lbs. per cubic inch.*

Volume of casting (6)=.546 cubic inches.
Therefore the weight of casting=.546 x 0.26.
" " " " =.1419 lbs.

(2) If the job shown in Diagram (7) is made of Machine steel what will its weight be?

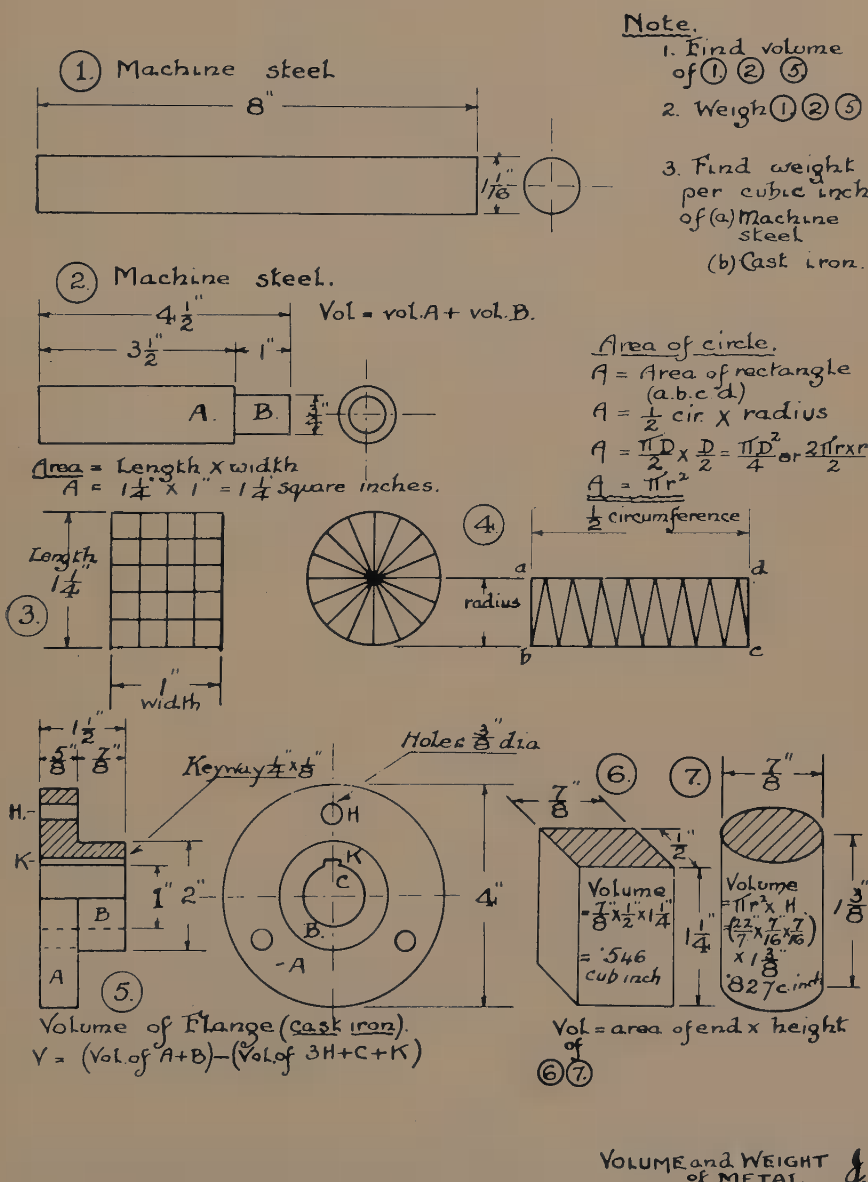
Note: Machine steel weighs 0.28 lbs per cubic inch.

Volume of casting (7)= .827 cubic inches.
= .827 x 0.28.
= .2315 lbs.

Question 1. Find the weight of a solid cast iron flange of the outside dimensions shown in diagram (5).

Note: This problem involves only 2 simple cylinders A and B.

Question (2). Find the weight of the casting as illustrated in diagram (5) with 3 holes H drilled out, keyway K cut out, and C bored out.


Note.
1. Find volume of 1 2 5
2. Weigh 1 2 5
3. Find weight per cubic inch of (a) Machine steel (b) Cast iron.
1. Machine steel
8"
1 1/16"
2. Machine steel.
4 1/2"
3 1/2"
1"
A.
B.
3/4"
Vol = vol. A + vol. B.
Area = Length x width
A = 1 1/4" x 1" = 1 1/4 square inches.
Length 1 1/4"
3.
1"
width
4.
Area of circle.
A = Area of rectangle (a.b.c.d.)
A = 1/2 cir. x radius
A = πD/2 x D/2 = πD²/4 or 2πr x r/2
A = πr²
1/2 circumference
a
d
radius
b
c
1 1/2"
5/8"
7/8"
H.-
K-
Keyway 1/4" x 1/8"
Holes 3/8" dia
H
K
C
B.
-A
B
A
1"
2"
4"
5.
Volume of Flange (cast iron).
V = (Vol. of A+B) - (Vol. of 3H+C+K)
6.
7.
7/8"
7/8"
1/2"
1 1/4"
1 3/8"
Volume = 7/8" x 1/2" x 1 1/4"
= .546 cub inch
Volume = πr² x H
= (22/7 x 7/16 x 7/16) x 1 3/8"
.827 c. inch
Vol = area of end x height
of 6 7
VOLUME and WEIGHT of METAL.

PULLEY SPEEDS AND LATHE SPEEDS.

Belts driving pulleys, like gears driving gears have the following functions:—

(1) They connect up two lines of drive.
(2) They can change the rotating speed.
(3) They can change the direction of rotation.

In diagram (1)) the driver runs at 200 R.P.M. (Revolutions per minute) and is an open drive, so that both pulleys rotate in the same direction. The pulleys are of different diameters, therefore the speed is changed because the belt contact as shown at A B represents one half a revolution of the large pulley, but it requires one complete revolution of the small pulley to have contact with this amount of belt.

From diagram (1) it may be seen that pulley speeds are inversely proportional to their diameters; that is a pulley that is half the diameter of its driver goes twice as fast.

If the speed of a driver and its diameter are known, and the diameter of the driven is known, the speed of the driven can be found.

Pulleys being driven by belt can be represented by the following equation:—

$$\left(\begin{array}{l}\text{Speed of Driven pulley} \\ \text{x its diameter}\end{array}\right) = \left(\begin{array}{l}\text{Speed of the driving pulley.} \\ \text{x its diameter.}\end{array}\right)$$

or $s \times d = S \times D.$

$$\therefore s = \frac{S \times D.}{d}$$

Example:—What will be the speed of the driven pulley or follower in diagram (1).

$$s = \frac{S. \times D.}{d}$$

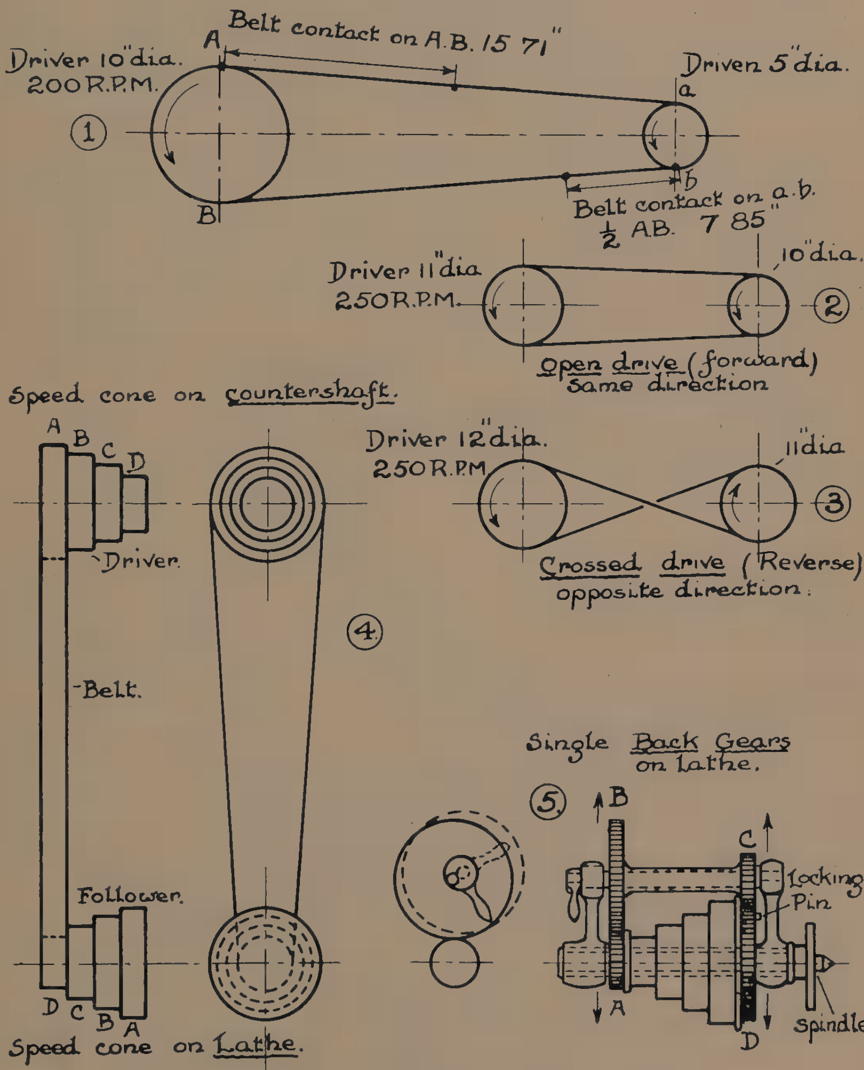
$$s = \frac{200 \times \overset{2}{\cancel{10}}}{\cancel{5}}$$

$$s = 400 \text{ R. P. M.}$$

Open drive. Diagram (2) shows an "open drive" connecting the main shaft and lathe countershaft, this gives to the machine the forward drive.

Crossed drive. Diagram (3) shows a "crossed drive" connecting the main shaft and lathe countershaft, this gives to the machine the "reverse drive" so that this belt is sometimes called the "backing belt".

Speed cone drive. Diagram (4) shows a speed cone on the countershaft driving by belt to a similar one in the opposite position on the



LATHE SPEEDS, PULLEY SPEEDS

lathe. It is known by various names such as "Speed cone", "Cone pulley", "Stepped pulley".

Spindle speeds obtained from speed cone. If the steps in the speed cone illustrated in diagram (4) have diameter (D=3¼″), (C=4¾″), (B=6¼″) and A=7¾″) work out the spindle speeds when the belt is on each step of the cone pulley.

Use of back gears. The lathe has four speeds driving direct with the speed cone fastened to the spindle through the locking pin and the spindle gear. If slower speeds are required the locking pin P must be loosened and the speed cone disconnected from the spindle gear. The speed cone now runs free on the shaft. If the back gears are put in as shown in diagram (5), the lathe spindle will be driven as follows:—

Speed cone attached to pinion A to B, through back gear sleeve to C, and from C to D, which is fastened to the spindle.

To find speed of spindle with back gears in—

Speed of driver gear x number of teeth of all drivers = Speed of follower gear x number of teeth of all followers

Example—Diagram (5). Find the speed of the spindle with back gears in when A has 28 teeth, B has 84 teeth, C has 28 teeth, D has 84 teeth, Belt on small step D on lathe cone, with lathe making 656 R.P.M.

$$S \times T \times T = s \times t \times t$$
$$656 \times 28 \times 28 = S \times 84 \times 84$$

$$\therefore S = \frac{656 \times \cancel{28} \times \cancel{28}}{\underset{3}{\cancel{84}} \times \underset{3}{\cancel{84}}} = \frac{656}{9}$$

$$S = 72.88 \text{ Revs. per minute.}$$

PULLEY AND BELT CALCULATIONS.

The beginner should understand how to calculate pulley speeds under various conditions as belts and pulleys are used universally in power transmission. Guesswork should never be used when setting up machines as suitable speeds required for various machines should be worked out as near as is practically possible to give the best results.

To find the size of a pulley to give a required speed—Diagram (1).

Given speed of driver 180 R.P.M. (S)
" diameter of driver 30″ (D)
" speed of pulley required 450 R.P.M. (s).

Find diameter of driven pulley (b).

Note: See pulley speeds and lathe speeds page (125).

$$s \times d = S \times D$$

then $$d = \frac{S \times D}{s}$$

$$d = \frac{\cancel{180}^{12} \times \cancel{30}}{\cancel{450}_{\cancel{15}}}$$

$\therefore$ $d = 12''$ diameter.

To find the size of a pulley for a compound pulley drive—Diagram (2).

The speed of the driving pulley X diameters of all driving pulleys = The speed of the last follower pulley X diameter of all follower pulleys.

In diagram (2) : page 129

A and C are drivers, B and D are followers.

$$\therefore S \times A \times C = S \times B \times D$$
$$1140 \times 6 \times 11 = S \times 24 \times 10$$

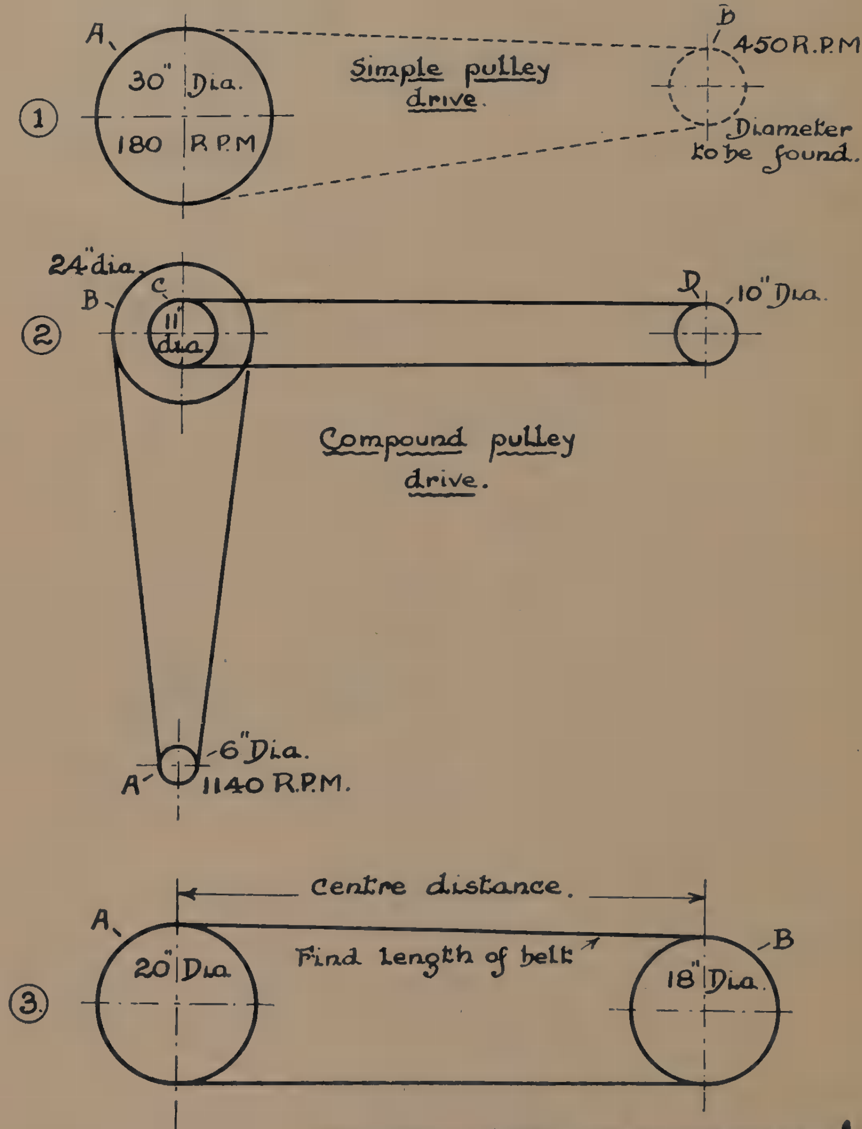
$$S = \frac{114\cancel{0} \times \cancel{6} \times 11}{\cancel{24}_{4} \times \cancel{10}} = \frac{1254}{4}$$

$$S = 313.5 \text{ R.P.M.}$$

To find the speed of a pulley in a compound pulley drive—Similar to diagram (2).

Given Speed of D, 313.5 R.P.M.

Find Diameter of D.



PULLEY and BELT CALCULATION.

$$S \times A \times C = S \times B \times D.$$
$$1140 \times 6 \times 11 = 313.5 \times 24 \times D.$$

$$D = \frac{\overset{285}{\cancel{1140}} \times \cancel{6} \times 11}{313.5 \times \underset{4}{\cancel{24}}} = \frac{3135}{313.5}$$

$$D = 10'' \text{ diameter.}$$

Conclusions: Diameter of driven pulley required as in diagram (1).

Rule: Multiply the diameter of the driving pulley by its speed in R.P.M. and divide by the speed of the driven pulley then the diameter of

$$B = \frac{30 \times 180}{450}$$
$$B = 12''$$

Compound pulley drive—diagram (2).

Rule: Divide the product of diameters of driving pulleys by the product of diameters of driven pulleys and multiply the quotient by the speed of first driving pulley.

$$\text{Speed of D} = \frac{6 \times 11}{24 \times 10} \times 1140 \quad \therefore \text{speed of D} = 313.5 \text{ R.P.M.}$$

To find the length of a belt when diameters are nearly equal—Diagram (3), when it is not convenient to measure with a tapeline.

Add the diameters of the two pulleys together, divide the result by two, and multiply the quotient by $3\frac{1}{7}$; add the product to twice the distance between the centres of the shafts

$$\text{or } \frac{(\text{Diameter A} + \text{diameter B} \times 3\frac{1}{7}}{2} + 2 \text{ C D}$$

Note: C D = Centre distance.

Example: If A = 20″ dia. and B = 18″ dia. and C D = 120″

$$\text{then length of belt} = \frac{20 + 18}{2} \times \frac{22}{7} \times 240''$$
$$\text{“} \qquad = 59.71'' + 240''$$
$$\text{“} \qquad = 299.71'' \text{ or } 299\tfrac{3}{4}''$$

TAPER TURNING BY SETOVER METHOD.

If a piece of stock 1 foot long were turned between centres in such a way that one end was 1″ larger than the other as in Diagram (1) the taper of such a piece would be 1 inch per foot. In Diagram (1) if point (a) were moved to point (b) a distance of ½ inch it would be in the position in which it was turned in the lathe, so that the tailstock would have to be set over towards the operator ½ inch. Therefore, the job shown in Diagram (1) has the following setover:

Setover = ½″ x the length of the work in feet.

$$\text{That is Setover} = \frac{\text{Taper per foot}}{2} \times \frac{\text{Length of work in inches.}}{12}$$

Example. What would be the setover of the job shown in Diagram (2) where the total length of the work is 6¼″ and the taper is a Morse Taper No. 3 or .602″ per foot.

Method (1).

$$\text{Setover} = \frac{\text{Taper per foot}}{2} \times \frac{\text{Length of work in inches.}}{12}$$

$$\text{or} \quad S = \frac{T}{2} \times \frac{L}{12}$$

$$S = \frac{\overset{.301}{\cancel{.602}}}{\cancel{2}} \times \frac{\overset{3.125}{\cancel{6.250}}}{\underset{6}{\cancel{12}}}$$

$$S = \frac{.9406}{6} = 0.1567$$

$$S = 0.157 \text{ inches.}$$

Method (2).

Most of the work done on the lathe is usually expressed in inches so that when calculations are being made the *taper per foot* could be changed to *taper per inch* as follows:

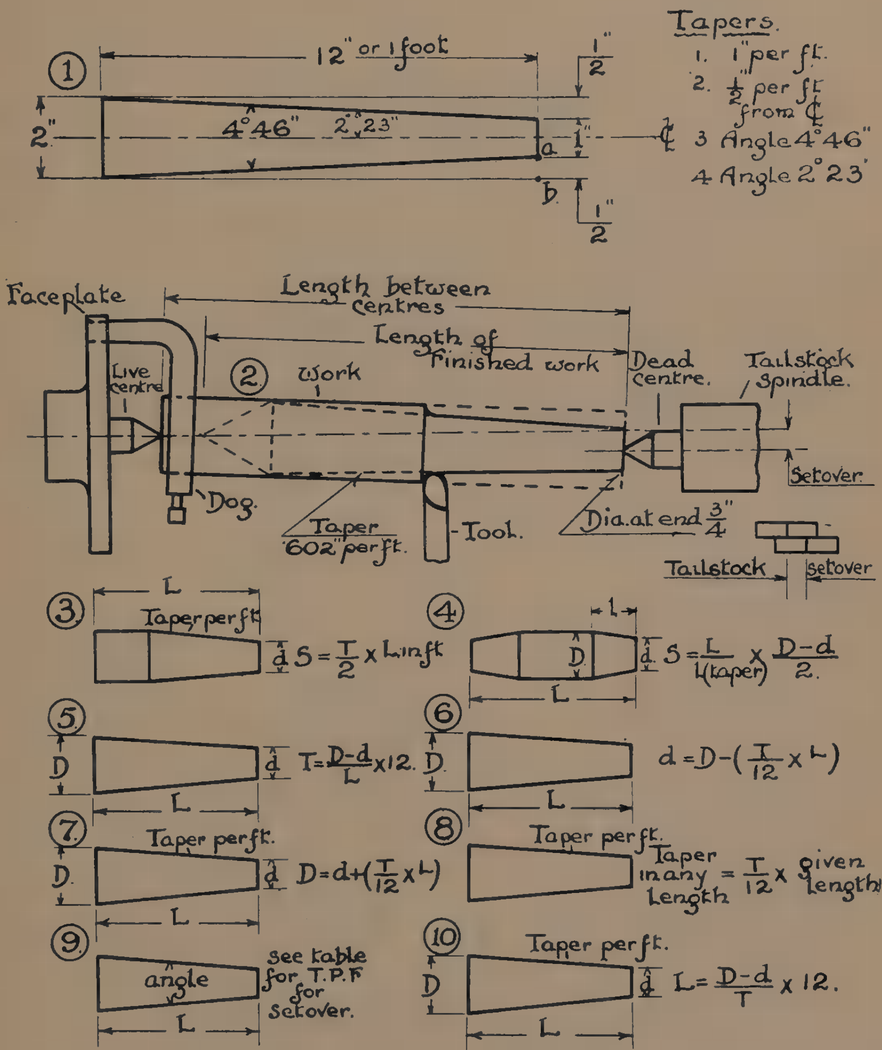
$$\text{Setover} = \frac{\text{Taper per inch}}{2} \times \text{Length of work in inches.}$$

Apply this method to example given above.

$$\text{Taper per inch} = \frac{\text{Taper per foot}}{12}$$

" " " $= \frac{.602}{12} = .05016$

" " " $= .0502''$ nearest to 3rd decimal place.



(Setover) TAPER TURNING.

$$\text{Setover} = \frac{\text{Taper per inch}}{2} \times \text{Length of working inches.}$$

$$\text{That is } S = \frac{T}{2} \times L$$

$$\overset{.0251}{S = \frac{\cancel{.0502}}{\cancel{2}}} \qquad \underline{6.250}$$

$$S = 0.157 \text{ inches}$$

Note: In Diagram (2) the length of the finished work 6″ is not considered but the length of the stock between centres is the important thing that influences all tapers by the setover method.

Diagrams (3) to (10) show the various data which may be given in taper work. Diagram (3) is the formula just illustrated in Diagram (2).

Definition of taper. Taper is the difference in diameter of a piece of work for a unit of length, usually 1 foot, for example taper 0.625 inches per foot. The taper may also be expressed in inches.

QUESTIONS ON SHOP MATHEMATICS.

1. How would you draw a line at right angles to another line (a) near the centre of the line (b) near one end of the line?

2. How would you bisect a line at right angles?

3. How would you draw a line parallel to another line?

4. How would you bisect an angle?

5. How would you lay out an angle equal to a given angle?

6. Lay out an angle of 60°, 45°, and 30°.

7. How would you lay out a right angle any size?

8. How would you prove that the circumference of a circle is approximately 3 1/7 times the diameter?

9. If a piece of cotton were wrapped around a 1 1/2″ cylinder 500 times how long would it be if it were stretched out in a straight line?

10. What do you understand by "cutting speed"?

11. What would be the cutting speed of a piece of round stock 1 1/4″ diameter running at 150 revolutions per minute?

12. What number of R.P.M. would be necessary for a piece of stock 1 3/4″ diameter to give a cutting speed of 65 feet per minute?

13. What do you understand by "Feed"?

14. Two pieces of stock the same diameter were running at the same speed, one had a feed of 1/16″ and one 1/64″. If the first was completely turned in 5 minutes, how long would the second piece take to turn?

15. What do you understand by "depth of cut"?

16. If one piece of stock were reduced to size in 10 minutes with a 1/8 depth of cut, how long would it take to reduce another piece of stock to the same size with 1/32 depth of cut with the same cutting speed and feed?

17. What is the weight of a cast iron cylinder 12″ long by 1 1/2″ diameter when cast iron weighs 26 lbs. per cubic inch?

18. What is the weight of a block of cast iron 6″ x 3″ x 2″ with a 1 1/4″ hole running through it lengthwise?

19. If 3 holes 7/8″ diameter are drilled in a round cast iron plate 5″ diameter and 3/4″ thick what is the weight of the plate when drilled?

20. If a driving pulley is 11″ diameter and runs at 250 R.P.M. and the follower pulley is 5″ diameter what speed does the follower run at?

21. The speed cone of a lathe and countershaft has steps 7¾″, 6¼″, 4¾″, 3¼″ diameter. If the countershaft runs at 220 R.P.M. what are the 4 possible spindle speeds of the lathe?

22. If the ratio of the back gears of a lathe is 7 to 1, work out the spindle speeds with the back gears in and with cone speeds as in question 21.

23. What size pulley is required for a machine to run at 1,100 R.P.M. when the driving pulley is 12″ diameter running at 250 R.P.M?

24. If a 7″ pulley on a motor runs at 1,200 R.P.M. and connects to a main shaft pulley 18″ diameter, and a man shaft pulley 11″ diameter drives another countershaft at 250 R.P.M., what size pulley is on the countershaft?

25. Calculate the length of belt on a machine when the centre distance between driven and driving shafts is 8 feet and the driving pulley is 14″ diameter and the driven pulley 16″ diameter.

26. What do you understand by "Taper per foot"?

27. If a piece of work is 6¼″ long and is required to be tapered to a No. 3 Morse taper to ¾″ at the small end, what would the setover be?

28. If a piece of work is 10″ long and has a tapered portion on one end 5½″ long measuring ¾″ diameter at the small end and 1″ diameter at the large end, what would the setover be?

29. A piece of tapered work is 6″ long with a diameter of ¾″ at the small end and 1″ at the large end. What is the taper per foot?

30. A crowned pulley is to be turned on an arbor 10″ long. The taper of the crown is ¾″ per foot. Find the setover of the tailstock.

31. What would be the cutting speed of a milling cutter 2½″ diameter running at 90 R.P.M.?

32. How many R.P.M. should a 3″ diameter steel cutter make when milling a square on a machine steel shaft?

QUESTIONS ON GRINDING.

1. How is a grinding wheel made?
2. What do you understand by a 60 grain size abrasive?
3. What is the difference between a "coarse" and a "fine" wheel?
4. What is the result of using a sharp cutting wheel and a dull wheel?
5. What is the proper method of mounting a wheel?
6. What threads are used on a grinder spindle? Why are they used?
7. What are the common shapes of wheels used? For what purpose are they used?
8. How should a grindstone rest be adjusted?
9. For what purpose is a wheel dresser used?
10. What is the primary shape of a lathe or planer tool?
11. What are the various angles given to a lathe tool called? What is the main reason for each angle?
12. How are abrasives used in the various methods of polishing?
13. How is a polishing wheel coated with an abrasive?
14. How would you polish (a) Flat stock; (b) Round stock; (c) stock with an irregular face?

SHOP SCIENCE

SPARK TEST FOR METALS.

If metal is placed in contact with the periphery of a grindstone, small particles of metal are thrown off by the cutting action of the thousands of sharp abrasive grains bonded together to form the wheel. The heat generated by friction is sufficient to heat up the small particles of metal and they fly into the air by the centrifugal action of the wheel. Generally they appear as a dull red streak of light, but instead of gradually dying out as would be expected, they suddenly ignite. It is evident therefore that some change has taken place in the particle of metal since it left the stone and the change is due to chemical action. The carbon in the metal has combined with the oxygen in the air causing the increased combustion as seen, for example, in the torpedo-shaped spark of common iron.

What to observe in testing metals. (1) The color of the spark as it leaves the stone and also after it explodes.

(2) The shape of the explosion of the spark and the appearance as it leaves the stone.

(3) The distance from the stone where the illumination or change occurs.

Common iron or wrought iron. Diagram (1). The particular distinguishing feature of common iron is its distinct torpedo-shape when it illuminates. This torpedo shape is present more or less in all *"Ferrous"* metals (that is metals made from iron or *"Ferrite"*). There is also a very slight bomb-like radial explosion present, just before the torpedo shape is seen, which is due to the presence of carbon.

Mild steel, diagram (2), throws a similar spark to that of common iron with a slight increase in the radial carbon spark.

Tool steel, diagram (3), has a good proportion of the carbon spark, while the torpedo-shaped spark is much more difficult to detect.

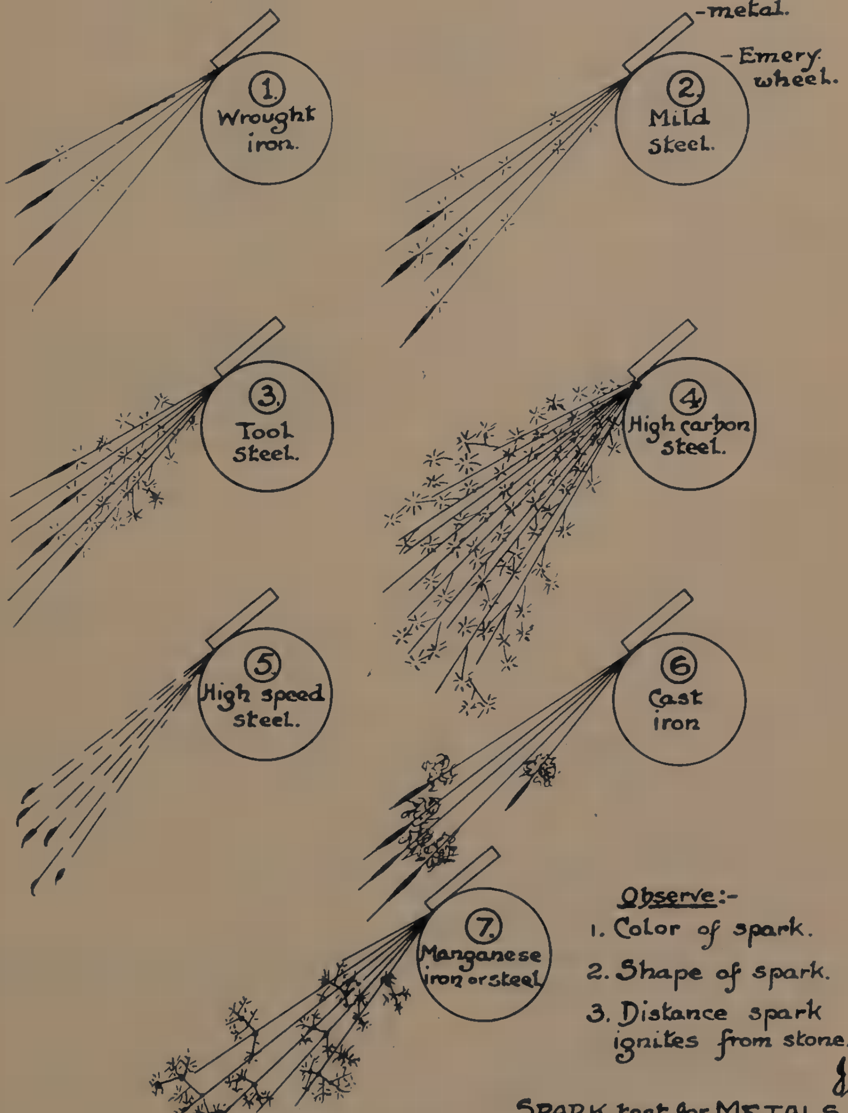
High carbon steel, diagram (4), has a very profuse showing of bomb-like radial sparks, igniting very close to the stone.

High speed steel, diagram (5). The spark appears like a dull red broken line with sometimes a slight globular ignition just before it dies out.

Cast iron, diagram (6), has a distinct torpedo shape with a feather-like tail. First dark red in color changing to a golden color.

Manganese iron or steel, diagram (7), has an illumination which shoots off at right angles to the general line of the spark and appears branch-like in its formation.

Note: The beginner should take samples of known metals to the grindstone and by sparking and observing each, formulate in his own mind the distinguishing features of each metal.



SPARK test for METALS.

FILING AND POLISHING.

It is just as necessary to know the details of Filing and Polishing as any other operation. Most people think because polishing is a commonplace operation that anyone can do it without any particular knowledge, but the beginner will find out by applying the principles given here that few people do it well.

Diagram (1) shows an enlarged section of a metal surface as it comes from the mill. The surface, as you have probably noticed, lacks brightness, in fact its surface is usually dark, for two reasons:—

(1) The surface is usually covered with iron oxide, a scale which has a black appearance.

(2) The surface, from a mechanical standpoint, is broken up into irregular serrations or grooves of various shapes and depths. This series of eminences and depressions has a tendency to absorb light, but not reflect it, consequently it does not appear bright to the eye.

Diagram (2) shows the section of a piece of work. The surface has no scale, but it has an occasional deep scratch. To polish this work the deep scratch must be removed either by a cutting tool, file or abrasive.

Diagram (3) shows a surface with scratches or serrations approximately the same depth but the serrated faces do not present a regular angle to the light.

In consequence of this, the reflected light is thrown off in various contrary directions, and therefore do not group together in reflecting light towards the eye of the observer. This surface therefore would not have the appearance of being well polished.

Diagram (4) shows a surface with regular serrations of equal depth, which presents a common similar angle to reflect the light. This, then is the beginning of a well polished surface. All that is required is to reduce the serrations smaller as shown in diagrams (5) and (6), until the naked eye cannot detect them. This operation of removing the serrations is carried out by using an abrasive such as emery or an artificial abrasive of still finer and finer grain size.

Diagram (7) shows another feature which influences the polishing even though the serrations are regular. If the serrations are made in various directions as shown in this diagram, the various sections will reflect light but in contrary patches.

Diagram (8) shows that the direction of all the serrations must be the same to produce good results.

Diagram (9) shows a good method of polishing tapered work, the stick carrying the abrasive cloth pivots on the lathe tool as a fulcrum and fits itself to the taper.

Diagram (10) shows a good method of polishing round stock of equal diameter throughout.

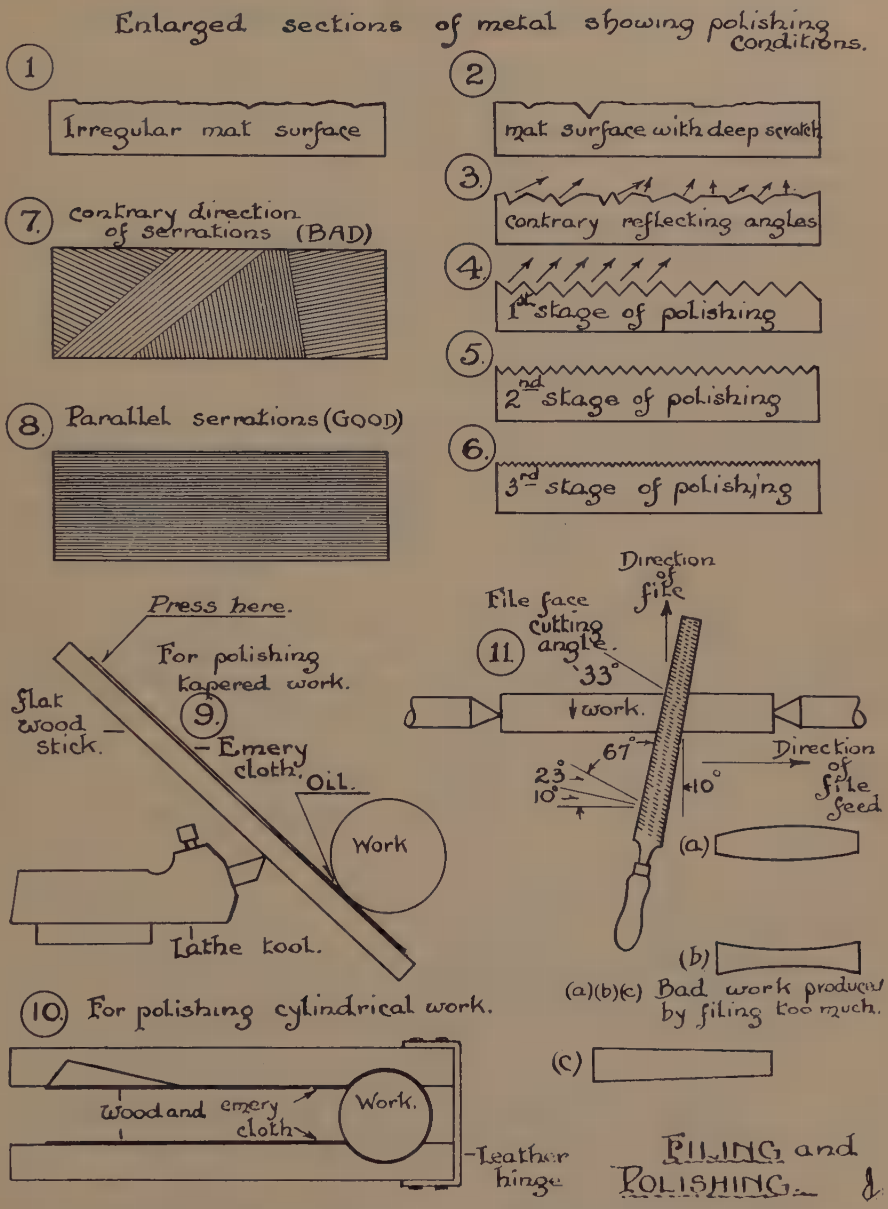


Diagram (11) shows the method of filing work in the lathe as the first step in polishing. Filing sometimes makes true work as left by the machine, out of round and in shapes as shown in (a) (b) (c).

Do not rotate the work too rapidly, and move the file slowly its full length from left to right as shown

THE PARTS AND REPRESENTATION OF A SCREW THREAD.

It is very important for the beginner to get a true conception of the screw thread, how it is shown in drawings, the names of the parts of the thread and the various shapes and uses of threads. Many references will be made later to the fundamental features explained here.

The helix. If the cylinders (1) and (3) represent the root and outside diameters of the thread shown in diagram (5) then the helix shown in diagram (1) is the path similar to the bottom or root of the thread and the helix in diagram (3) is the path similar to the top of the thread. If a triangular piece of paper is cut out as in (2), it will be seen that the hypotenuse of the triangle is a straight line, but when wrapped around the cylinder it appears to be curved, so that a helix is a path around a cylinder making regular progression.

Angle at the root and top of thread. By a simple comparison of the triangles shown in diagrams (2) and (3) it can readily be seen that the angle at the root of the thread is greater than the angle at the top of the thread. This has a very important application when grinding tools for cutting threads to obtain sufficient clearance for the helical angle of the thread.

Representing threads in drawings. Large threads are occasionally drawn as shown in diagram (5), but the general practice is to draw threads by the approximate method as shown in diagram (6), the particulars regarding the number of threads and the kind of thread being shown by a suitable notation.

Pitch of a thread is the distance from one thread to the next thread to it and is usually expressed as 1/8″ pitch, 1/8″ P, or 8 threads per inch.

Lead of a thread is the amount a nut progresses on a thread in one revolution.

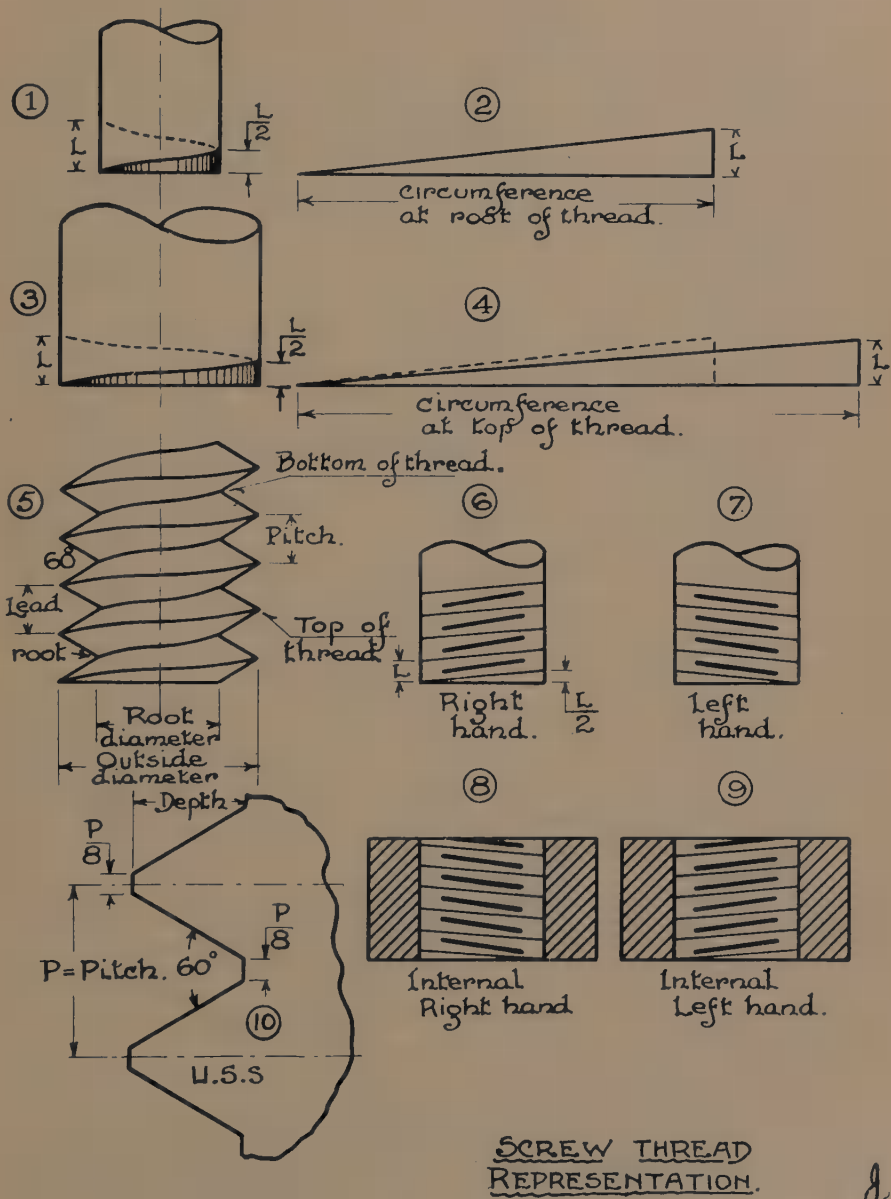
Note: In a single thread "lead" and "pitch" are equal. In a double thread "lead" equal twice the "pitch". In a triple thread "lead" equals three times the "pitch".

Right hand threads. Diagram (6). If a threaded bolt is stood up on its end a right hand thread will incline to the right or if a nut is put on, it will progress on the bolt when the nut is turned to the right.

Internal right hand thread. As shown in diagram (8) the nut is in section showing the back half of the threads inclined opposite to the external threads as seen from the front, but if the helix is traced around the back of the threaded object the reason for the opposite inclination will be noted.

Left hand threads (Diagram 7) incline in the opposite direction to right hand threads. If a bolt were stood up on its end the nuts will progress if turned to the left and the threads will incline to the left.

United States Standard thread, usually abbreviated as U.S.S., is the form of thread most commonly used in the United States and Canada. Other forms of threads and their uses will be described later.


1
2
3
4
5
6
7
8
9
10
L
L/2
Circumference at root of thread.
Circumference at top of thread.
Bottom of thread.
Pitch.
60°
Lead
root
Top of thread
Root diameter
Outside diameter
Right hand.
Left hand.
Depth
P/8
P=Pitch. 60°
U.S.S
Internal Right hand
Internal Left hand.
SCREW THREAD REPRESENTATION.

FASTENING METALS TOGETHER.

Metal can be fastened together in a variety of ways, some permanent and some temporary. Some forms of fastenings are suitable for one kind of work and unsuitable for another. Sometimes it is necessary to select a form of fastening on the basis of cost, but under all conditions the best and most suitable form of fastening should be secured in keeping with the results required.

Rivets. Diagrams (1) and (2) show two forms of riveted joints which are permanent fastenings, that is the rivet is driven cold or hot depending upon its size with the intention of not being taken apart again. When rivets are driven hot, on cooling they exert an increased pressure on the plates drawing them closer together.

Application—Constructional steel work, boat building, etc.

Diagram (3) shows a piece of round stock reduced to a shoulder and riveted into the countersink at the back of the plate.

Bolts (4), are varied in design according to the use to which they are put, but generally a bolt is used where parts may be required to be taken apart and where both sides are accessible. The length of a bolt is measured from inside the head to the end of the screw.

Cap screws (5), are used where parts may have to be removed and when it is impossible or difficult to gain access to the under side. A hole is drilled in the body of metal to which the part is to be attached, the hole is then tapped to suit the cap screw and the parts assembled, the head of the cap screw pressing the parts together.

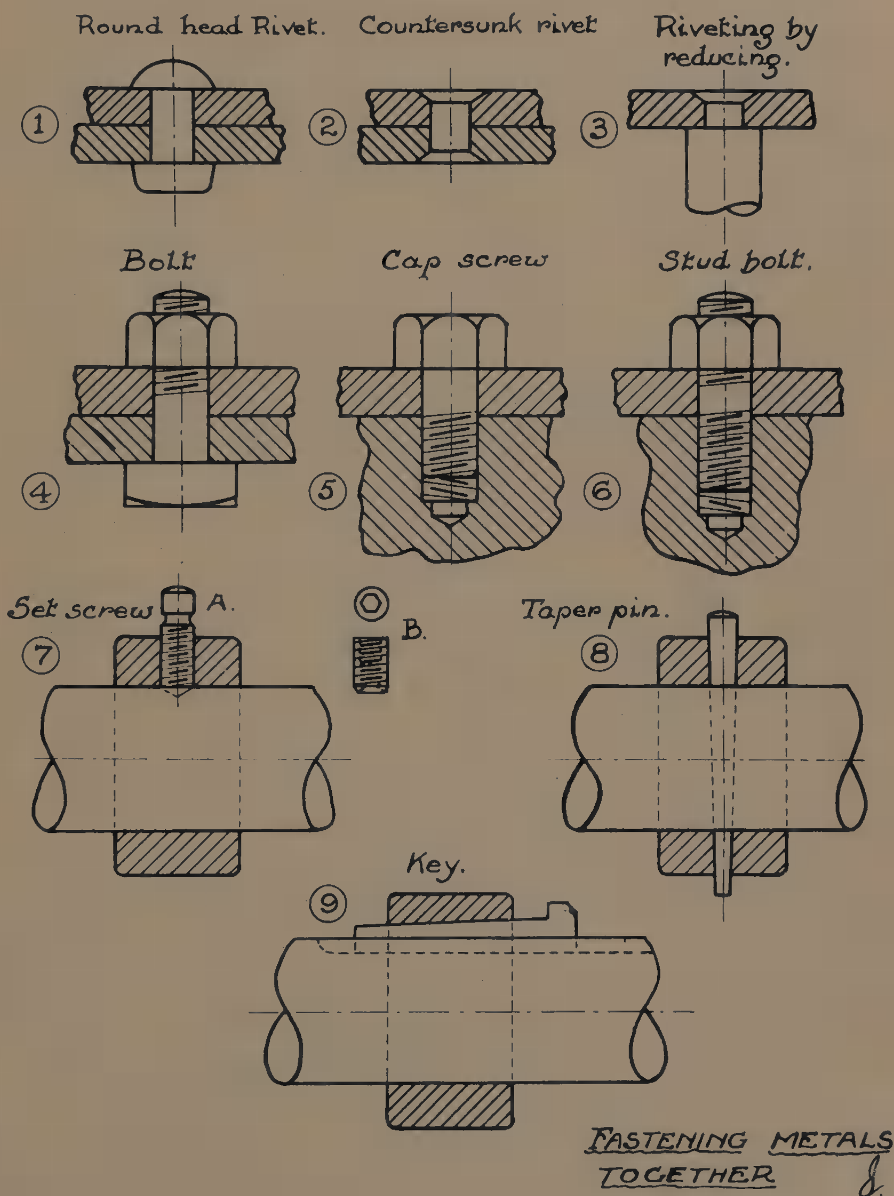
Stud bolt (6), has a very similar general use to a cap screw, except that the screw of the stud bolt is retained in the work to which the part is fastened while the nut is removed. This is sometimes a distinct advantage over the cap screw, because it is easier to find the location of the parts when re-assembling. The stud bolt screw is fastened to the metal by using a special wrench called a "stud driver".

Set screws (7), are varied in design, the socketed set screw (B) shown is much safer than the square head type (A). Set screws are used to press against a piece of metal and by friction prevent it from moving in relation to the other piece. Example, collars on shafts, etc.

Taper pins (8), have a similar function to set screws, they prevent parts from moving endwise on a shaft.

Keys (9), are varied in design for various uses, but they are usually iron or steel wedges used to fasten wheels, pulleys, etc., to shafts. The key compels the part to move in rotation with the shaft and also prevents any endwise movement which may put the part out of true running position with some other part. *Example*: Pulley keyed on a motor and a corresponding pulley on the line shaft.

Types of keys. Gib keys as illustrated in diagram (9), woodruff keys, feather keys, etc.


Round head Rivet.
Countersunk rivet
Riveting by reducing.
1
2
3
Bolt
Cap screw
Stud bolt.
4
5
6
Set screw
A.
B.
Taper pin.
7
8
Key.
9
FASTENING METALS TOGETHER

THE BUILDING AND USE OF A FORGE FIRE.

If a suitable furnace is not available it may be necessary to use a forge fire to provide heat for Hardening, Tempering, Casehardening, and annealing. The beginner should be able to build a forge fire correctly and know how to use it to advantage.

The forge. Most forges are made with a cast-iron hearth with a bowl or depression in the centre for the fire. In the bottom of the bowl is a hole through which the blast of air is forced. The blast opening is usually made in a separate piece of cast iron, which can be replaced if burnt out, and is known as the "Tuyere". The Tuyere controls the blast and prevents to some extent cinders from dropping down into the blast pipe.

Coal used. The coal used for a forge fire should be of the best quality bituminous or soft coal. The coal is mixed with water and when put on the fire and "tamped" or pressed down should cake up, form coke and not break into small pieces.

The fire. In building the fire the ashes, cinders, etc., should be cleaned away from the centre of the forge down to the tuyere, leaving some of the old coke on the sides as shown in diagram (1). A block of wood is placed over the tuyere and "green coal" (coal mixed with water) is "Tamped" down around the block as shown in diagram (4). The block is then removed leaving a hole into which shavings, oily waste, or some other easily lighted material is placed and set on fire, and some coke left over from a previous fire is placed on top. The fire should be kept up until the inner section of green coal has been made into coke as shown in diagram (5), this coke is then used in the fire and fresh green coal tamped around it.

The fire is made made up of three parts:—

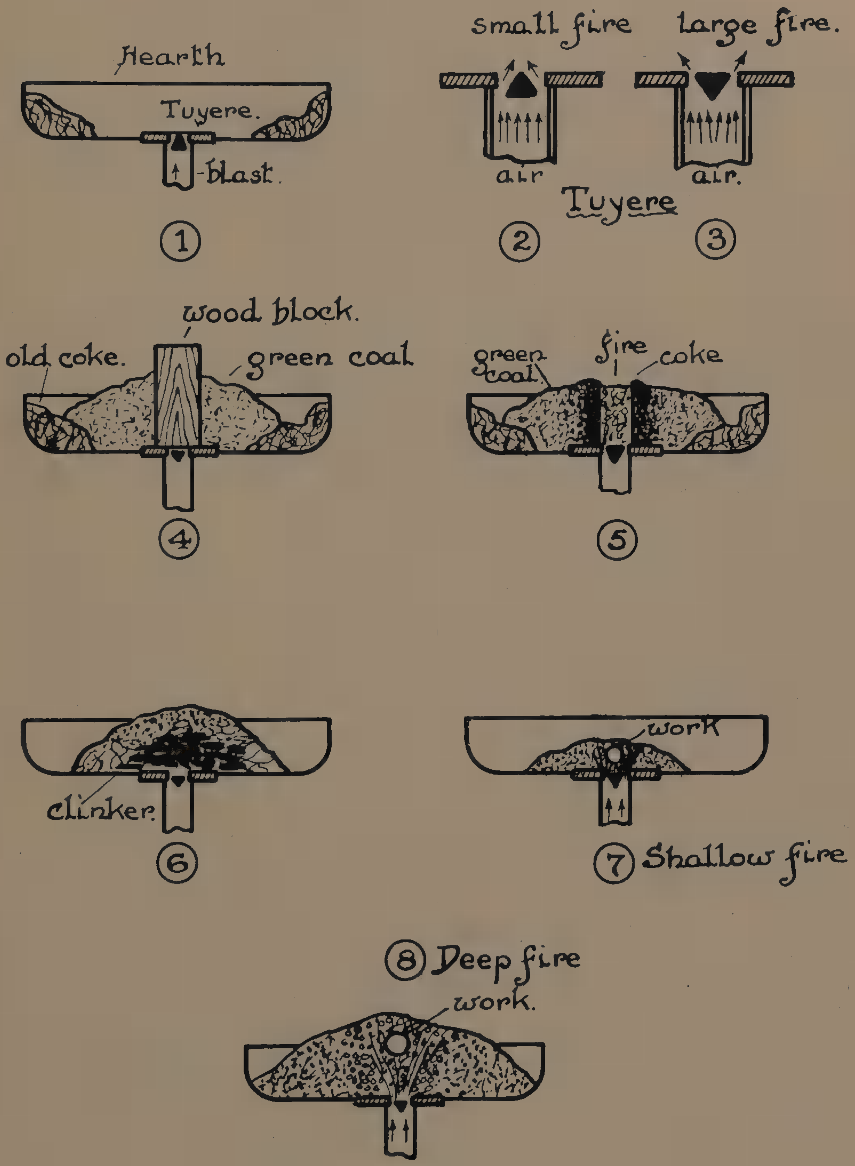
(1) The centre where coke is burning called the fire.
(2) A ring around the fire where coke is forming.
(3) Outside the coke ring is a ring of green coal.

A dirty fire. Diagram (6) shows a fire, the bottom of which is full of "clinker" (burnt out fuel massed together). The clinker prevents the user from obtaining a hot fire and should be removed from the fire as quickly as it forms.

Oxidising fire. Coal requires a certain amount of air to burn properly and as it burns it consumes the oxygen from the air. When too much blast is used the oxygen is not all burned out in the air and will affect the heated iron in the fire. Whenever a piece of hot iron comes in contact with the air the oxygen of the air attacks the iron and forms an oxide called "Iron oxide".

Heating work. Diagram (7) shows a shallow fire with very little heat thus exposing the work to the blast and causing irregular heating.

Diagram (8) shows a deep fire with the work protected from the direct blast and if the work is turned in the fire it will be heated satisfactorily.



THE FORGE FIRE.

EXPERIMENTS IN HEAT TREATMENT. (1).

The Heat Treatment of metals is a most interesting and scientific study and forms a very important branch of industrial progress. It does not matter how well a tool may be made, it must receive the proper heat treatment to give it the kind of hardness or strength for the work it has to do. The experiments given here will at least give the student a simple idea of the operations of:—

Hardening.
Tempering.
Casehardening.
Annealing.

Experiment (1), diagram (1). Take a piece of 80 point carbon steel $\frac{1}{2}''$ diameter in an annealed or softened condition, divide it into sections with the point of a lathe tool about $\frac{1}{16}''$ deep and stamp each section with a number as shown. Heat the bar with a varying heat throughout its entire length (diagram 2) so that one end is a black heat and the other end a sizzling white heat, then quench in water No. 1 end first.

Magnet test. If a magnet is used to test the bar immediately before quenching it will be noticed that the colder part of the bar (6 to 10) is magnetic and the hotter part (1 to 5) non-magnetic.

Breaking test. Break off the samples with a hammer in the vise diagram (3), it will be noticed that sample 1 can be broken easily with the hand. Sample 2 with a very light tap of the hammer, whereas No. 8 and No. 9 are very tough.

Magnifying test. Examine the fractures of the samples in comparison with each other beneath an ordinary magnifying glass and it will be observed that No. 1 (the burnt or overheated steel) has a very coarse crystalline fracture, that No. 5 has the finest and most even fracture and No. 9 a fibrous fracture.

File test. Test each sample by filing it with the heel of a file and note particularly whether the file slips over the sample or "bites" and cuts into it.

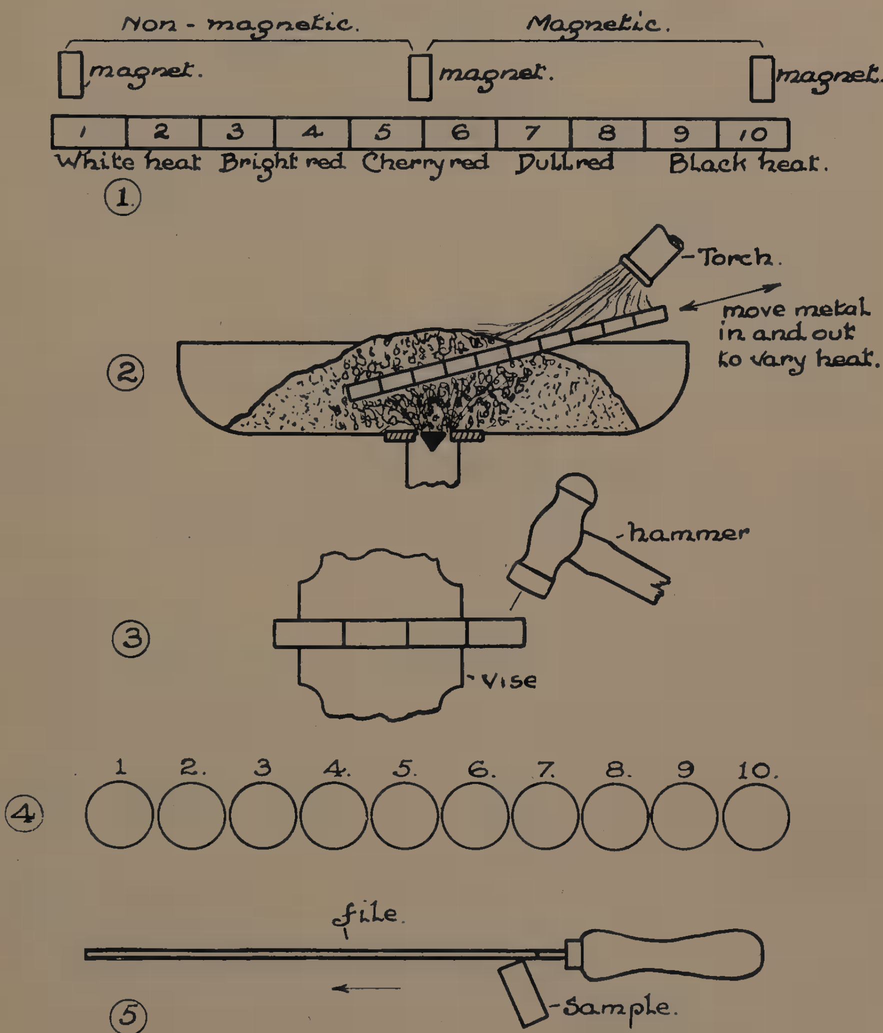
It will be noticed that samples No's. 1 to 5 are hard and No's. 6 to 10 soft.

Conclusions. (1) That when steel is heated it reaches a temperature at which it becomes non-magnetic (Sample 5) and it is noted that the sample No. 5 is the best hardened sample, therefore it is evident that the proper "Hardening Heat" for steel can be found by testing it with a magnet.

(2) That steel that is burnt is absolutely rotten and useless for any purpose, and can only be thrown away. That any heat in excess of the proper hardening heat does not give the best results.

(3) That the appearance of the fracture of steel helps considerably in judging the effect of the heat treatment.

(4) That filing steel after hardening will denote whether the steel is hard or soft, but will not define correct hardness or the difference between sample No. 1 and No. 5.



Experiment for HARDENING HEAT. J

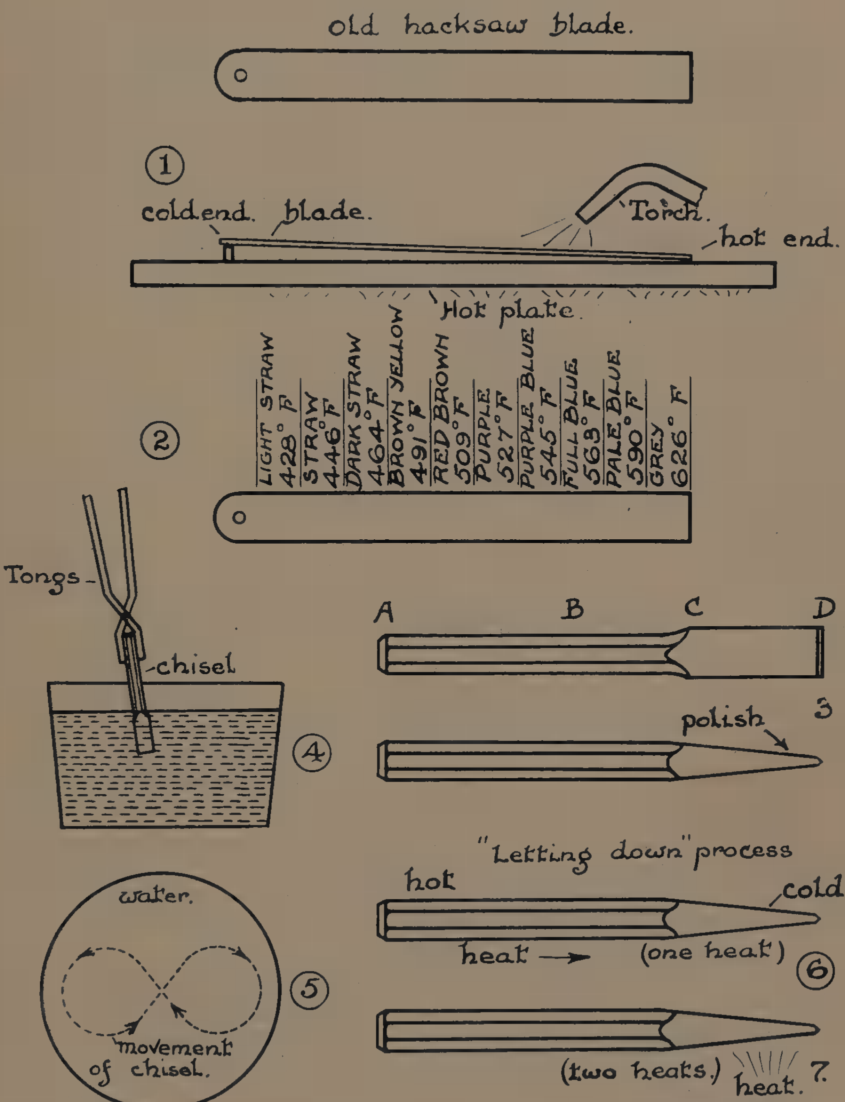
EXPERIMENTS IN HEAT TREATMENT. (2).

The "letting down" process of hardening and tempering. Experiment (1). Take an old power hack saw blade, grind and polish the surface, then place it inclined on a plate of metal and apply a varying heat, so that one end is much hotter than the other (diagram 1). Colors will soon appear and if care is exercised the colors should vary as shown in diagram (2). This range of color thus produced by heat is known as the "Color scale", each color representing some definite temperature. The color scale can be produced on iron or steel and is really a very thin film of "oxide" which can quickly be removed by polishing.

This color scale is very useful, it denoting the temperature required when heating objects to temper them. The heat should always be a gradual one, so that the colours elongate or stretch out making it possible for a finer selection of colour and temper.

The "letting down" process of hardening and tempering steel brings in the use of the colour scale for tempering. This method of hardening and tempering is considered obsolete to-day, although it is often used when hardening and tempering one or two tools. Many men are expert at judging proper hardening heat and temper heat by colour, with experience it becomes a matter of intuitive skill. Modern heat treatment does not recognize such approximate methods, and uses scientific methods which can be duplicated as required as will be learned later.

Diagram (3) shows a cold chisel which is to be hardened and tempered by the "letting down" process in one heat. Heat the tool from A to D in a suitable fire or furnace, withdraw the steel occasionally and test with a magnet. When the steel first shows signs of being non-magnetic quench C D in cold soft water as shown in diagram (4), moving the tool around in the water and up and down to vary the heat between B C so that there is no distinct line of separation between the hot and cold metal. Allow sufficient time for the heat to be withdrawn from the point C D, then remove from the water and polish C D with an abrasive. Test also with a file to see that hardness has been obtained, then allow the heat to move from A B towards the point. A light straw first appears, followed by browns, purples, and blues. When purple reaches the point of the tool plunge the tool in water to "hold the temper". It is necessary to grind the point being tested because the outer steel has been slightly decarbonized and would likely be soft; this decarbonizing is caused by the carbon being burnt out from the outer steel in the fire.


old hacksaw blade.
1
cold end.
blade.
Torch.
hot end.
Hot plate.
2
LIGHT STRAW 428° F
STRAW 446° F
DARK STRAW 464° F
BROWN YELLOW 491° F
RED BROWN 509° F
PURPLE 527° F
PURPLE BLUE 545° F
FULL BLUE 563° F
PALE BLUE 590° F
GREY 626° F
Tongs
chisel
4
A
B
C
D
polish
3
"Letting down" process
hot
cold
heat
(one heat)
6
water.
movement of chisel.
5
(two heats.)
heat.
7

TEMPERING.

ANNEALING AND CASEHARDENING.

Annealing is a process of heating steel to soften it or to remove all the strains caused by rolling, hammering or forging.

Method (1), diagram (1), shows one of the most satisfactory methods of annealing, that is to pack the pieces between layers of charcoal in a cast iron box, so that no two of the pieces touch each other or the sides of the box. After fastening on the cover tightly the box should be placed in the furnace and brought to the proper heat.

Example: A piece of high grade tool steel one inch in diameter should remain at a temperature from 1375 to 1650 degrees F. depending on the steel, for one hour after the box has heated through. Larger pieces should remain in the furnace longer. The box and contents should cool off with the furnace.

Annealing heats should be higher than hardening heats to allow a margin to overcome any strains or imperfections which may appear later in hardening.

Heat low carbon steels to 1650°F.
Heat high carbon steels to 1375F.

Materials to use in annealing. Powdered charcoal, charred bone, Charred leather, Mica, Slacked lime, Sawdust, Sand, Fire Clay, Magnesia, Refractory earth.

Quick annealing or "water annealing". Diagrams (2) and (3). Occasionally it is necessary to anneal a piece of steel quickly. It is not as satisfactory as the method previously described. The steel is heated to a red heat and held in the dark until all color has disappeared, or tested with a dry pine stick until the steel fails to spark the wood, then quenched in water. Sometimes the steel is heated then buried in slacked lime to cool.

Casehardening is a process of hardening the surfaces of articles made of wrought iron or machinery steel.

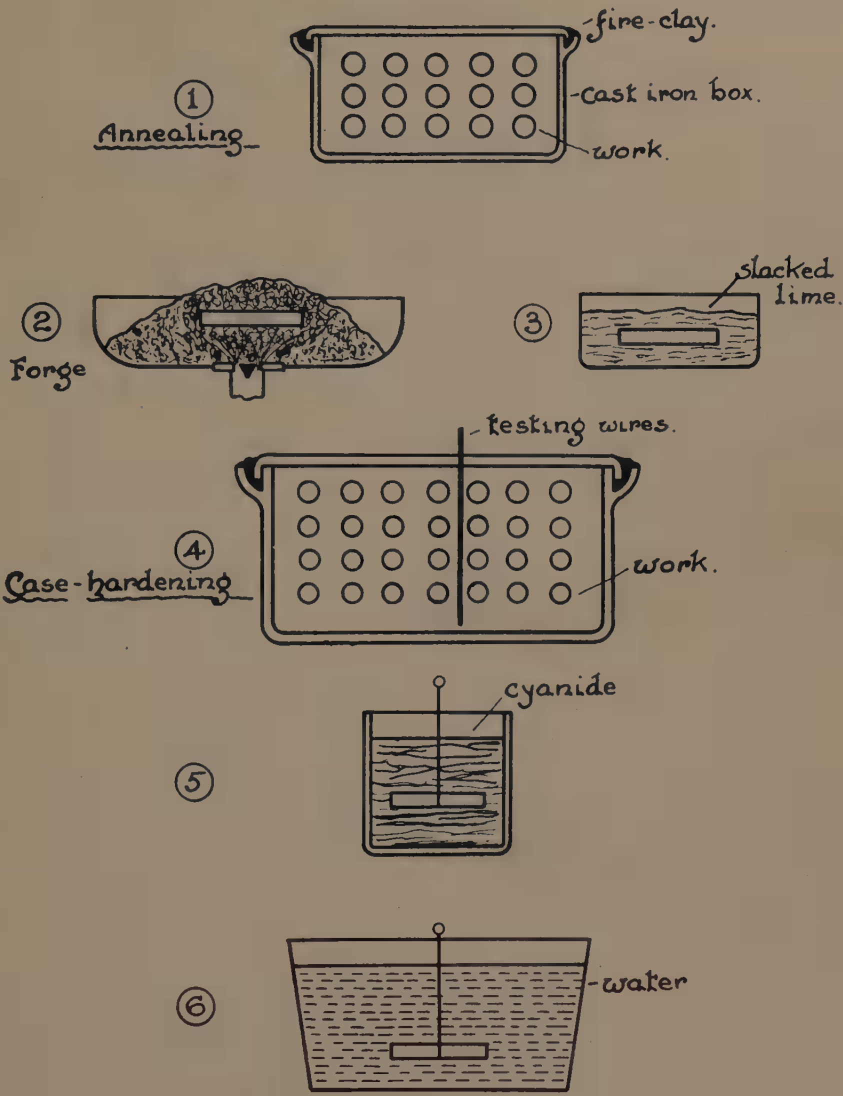
Method. The articles to be casehardened are heated in contact with some carbonizing material which converts the outer part into steel, they are then allowed to cool and afterwards reheated and quenched in water or oil to harden the outer surface.

Diagram (4) shows the best method for casehardening a number of parts. A cast iron box is used as shown and the work is heated to about 1,800 degrees F. and the heat should be regularly maintained. When the wires, on being withdrawn with tongs and are found to be red the full length, begin to time the operation.

Time required. The length of time is governed by the depth of casing required, and indirectly by the size of the work.

Examples. 5/8" round mild steel heated with a carbonizing material at cherry red (1652 degrees F) for 6 hours had a penetration of 1/32".

A similar piece heated to bright red 1832 degrees F for 6 hours was penetrated 1/16".



ANNEALING and CASE-HARDENING.

Quick method. Heat article as shown in diagram (5) in molten cyanide of potassium for from 15 to 30 minutes according to depth required. Quench in water.

Colouring. Very beautiful colour effects are obtained by quenching from a cyanide bath into a water tank disturbed by air bubbles.

PROPERTIES OF METALS.

Aluminum can be cast and spun into various forms, it does not rust and is widely used for kitchen utensils. When turning use a shearing tool with kerosene or benzine as a cutting lubricant.

Brass is the copper zinc alloy containing one-third zinc and two-thirds copper. Lead is frequently added to make it machine more easily. Tin is sometimes added to give greater strength.

Copper is a good conductor of heat and electricity and is used considerably in making alloys. It will not rust and is very malleable.

Bronze is a copper tin alloy containing approximately 10 per cent. tin and 90 per cent. copper; sometimes lead and zinc are added. It has a darker colour than brass and is much harder.

Cast iron can be molded to any desired shape. It rusts less than wrought iron or steel and has a very high compressive or crushing strength. It is liable to hidden defects or "blowholes" and has a very hard skin, while the metal beneath the skin is comparatively soft and crystalline in structure. It cannot be forged and does not withstand shocks and jars and owing to its brittleness breaks very easily. It is subject to internal stresses, set up from unequal cooling in the mould and often when the skin is removed it is allowed to season before final finishing. It is used considerably by engineers where great compressive strength is desired and in machine details where shape, mass and weight are of more importance than strength.

Wrought iron is the product obtained by extracting the carbon from cast iron by passing the blast through it or over it, while in a molten condition. It is tougher than cast iron and is capable of withstanding a greater tensile and transverse stress than cast iron. It is very ductile iron in that it is free from slag. It is made by the open hearth method and can be forged and welded readily.

Machine steel, mild steel or "Bessemer" steel, differs from wrought iron in that it is free from slag. It is made by the open hearth or Bessemer process and is known as a "low carbon'5' steel, but it is only a little better than iron in general qualities.

Carbon steels. This term generally applies to steels used for cutting and small tools and is what might be termed a pure steel as it is a combination of iron and carbon, other elements appearing only as impurities. The carbon content ranges from 50 to 150 points, that is .5% to 1.5%, 50 point carbon steel is hard enough when hardened for some cutting tools and 100 point carbon gives, when hardened the limit of hardness of this kind of steel, being very nearly hard enough to resist being scratched by a diamond.

High speed steel is an alloy steel used for cutting tools. It is made up in varying quantities of tungsten, molybdenum, manganese, chromium carbon and vanadium.

By use of these steels cutting speeds have increased considerably, sometimes as much as twice or three times that required for carbon steel tools.

— SHOP TESTS FOR METALS. —

Method of making test or Observation	With the eye.	Drop Samples on Concrete floor.	Test with file or hammer	Test lightly on grind-stone.	File, turn drill. polish	Heat and quench in water.	Test with hammer and vise.
Name of Metal.	Color or Fracture	Sound or Ring	Hard or Soft.	Spark test	Working properties	Hardening properties	Bending qualities
Aluminum (cast) " (wrought)	Bluish Silver white.	dull	Malleable soft	none	use a shear tool. easy to work	none	very good
Brass (cast). " (rolled) " (Muntz metal)	yellow	fair ring.	Malleable soft	none	good	none	good
Copper (cast) " (wire)	red brown.	dull.	Malleable Soft.	none	good	none	very good.
Bronze (gun metal)	dark red brown	high ring	Brittle. hard	none	fair	none	fair.
Iron (cast " (wrought)	grey crystalline dark grey fibrous.	dull dull	Brittle. Malleable	Torpedo feathery Torpedo	good	none case hardens case-hardens	none very good.
Steel (machine) cold rolled	grey fibrous	slight ring.	Malleable soft	Torpedo with slight offshoots	good	case-hardens	good
Steel (tool) low carbon content	light grey. fairly fine fracture	high ring.	fairly hard	radial explosive spark	fair	hardens fair.	good
Steel (tool) high carbon content.	light grey fine fracture	very high ring.	Very Hard	profuse radial explosive spark	difficult	hardens good.	brittle
Steel (high speed)	medium grey velvety fracture	slight ring.	hard.	like a broken line	difficult	hardens	brittle

QUESTIONS ON SHOP SCIENCE.

1. What do you observe when judging a metal by its spark?
2. What is it that causes a heated particle of metal to illuminate or ignite?
3. What are the features of the spark from cast iron, common iron, low carbon steel, carbon tool steel and high speed steel?
4. What do you understand by a polished surface?
5. How would you proceed to obtain a good polished surface?
6. How would you file work in the lathe to obtain a good surface?
7. Is it advisable to file work after turning?
8. How would you polish lathework?
9. What is a "helix"?
10. Why is the root of a thread inclined more than the top of a thread?
11. Describe a right hand thread and a left hand thread.
12. Sketch the form of a U.S.S. thread.
13. Why is the section of an internal thread inclined opposite to an outside thread to which it fits?
14. Sketch and describe the use of a round head rivet, a countersunk rivet, a bolt, a capscrew, a stud bolt, a set screw, a taper pin and a gib key.
15. How is a forge fire built,
16. What are tuyeres? Why are they necessary?
17. What is "green coal"?
18. How can coke be made in a forge fire?
19. What do you understand by a dirty fire and an oxidising fire?
20. What is the effect of a deep fire as compared with a shallow fire?
21. What do you understand by the "Hardening heat" of a piece of steel?
22. How would you find the hardening heat when heating steel?
23. What is the effect of "overheating" steel?
24. How can you tell when steel is hardened?
25. What can you observe by fracturing steel after hardening?
26. Why is it necessary to temper steel after hardening?

27. What do you understand by the "colour scale"?
28. How can you harden and temper in one heat?
29. How should work be quenched to harden?
30. What is annealing?
31. How are parts annealed satisfactory in quantities?
32. How would you anneal one piece of work ?
33. What materials may be used in annealing?
34. What do you understand by "quick annealing"?
35. What is casehardening?
36. What metals are usually casehardened.
37. What kind of work needs casehardening?
38. What materials may be used for casehardening?
39. How would you caseharden a quantity of articles efficiently,
40. How would you caseharden one article quickly?
41. How would you obtain colours by casehardening?
42. What simple tests can you apply in a shop to distinguish one metal from another,
42. Name some of the simple properties of Aluminum, Brass, Copper, Bronze, Cast iron, Wrought iron, Machine steel, Carbon steels (High and low), High speed steel.

GLOSSARY OF TERMS

Abrasive. A substance used for abrading, as for grinding, polishing, etc. The principal abrasives now used are emery, tripoli, pumice, rouge, which are natural abrasives, and silicon carbide and aluminum oxide, which are artificial abrasives sold under various trade names such as Crystalon and Alundum, as sold by The Norton Company.

Alignment. Laying out, or regulating to a line. *"Setting the lathe in alignment"* means, that work rotating between centres will be parallel when cut by tool, which is controlled by carriage movement.

Backlash. A slackness of movement between machine parts such as the slackness in the fitting of a screw and nut.

Blast. Air under pressure.

Burr. A thin, ragged edge of metal.

sear

Chip pressure is the pressure exerted on a cutting tool as the chip is removed from the material being cut.

Ferrous metals are metals containing Ferrite or Iron.

Finishing machining to exact size with a fine cut and producing a smooth finish on the work.

Fillet. A rounding of the corner of metal, noticeable in cast metals, to give strength.

Lead is equal to "pitch" in a single thread, but twice the "pitch" in a double thread. It is the amount of progression or movement of a nut along a screw in one revolution.

Malleable. A malleable metal is a metal that is not brittle but can be bent slightly without breaking.

Mandrel or arbor. A tapered piece of round steel used for mounting and driving work.

engranar **Mesh.** Putting gears in "mesh" means, engaging the teeth so that they will drive.

Parallel. A block of metal with parallel sides used for setting up work above a surface but parallel with it.

Periphery is the distance around a cylinder or the circumference of a circle.

Pinion. A small gear.

Pilot hole. A small hole drilled previous to drilling a larger hole. It allows a free passage for the web or centre of the drill.

Pitch of thread is the distance on a screw from one thread to the next thread. Expressed pitch ⅛″ – 8 threads per inch.

100-point carbon steel defines the carbon content or quality of the steel. 100-point equals one per cent. carbon.

Roughing. An operation which removes the rough irregularities of metal and leaves it almost to size.

Scale or oxide is rapidly produced when metal is heated and exposed to the air. Iron Oxide is a combination of Iron and the Oxygen from the air.

Serrated. A saw-like condition, or a series of scratches or grooves.

Snagging. Rough grinding to remove the hard skin or irregularities on Cast Iron.

Spotting. Making a small cone-like recess central with the rotating work to assist a drill in finding the correct location for drilling.

Tangent. A straight line which touches a circle but does not cut it.

TABLES

CUTTING SPEEDS and FEEDS for TURNING TOOLS.

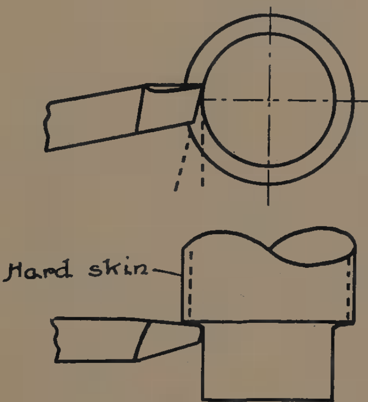
STEEL:- Standard 5/8" Tool.

Depth of cut in inches.	Feed in inches.	Speed in Feet per min for Tool to last 1½ hours before regrinding. Soft Steel.	Medium Steel.	Hard Steel.
1/16"	1/64"	548	274	125
	1/32"	358	179	81·6
	1/16"	235	117	53·3
3/32"	1/64"	467	234	106
	1/32"	306	153	69·5
	1/16"	200	100	45·5
	3/32"	156	78	35·5
1/8"	1/64"	417	209	94·8
	1/32"	273	136	62
	1/16"	179	89·3	40·6
	3/32"	140	69·8	31·7
3/16"	1/64"	362	181	82·2
	1/32"	236	118	53·8
	1/16"	155	77·4	35·2
1/4"	1/64"	328	164	74·5
	1/32"	215	107	48·8
3/8"	1/64"	286	143	65

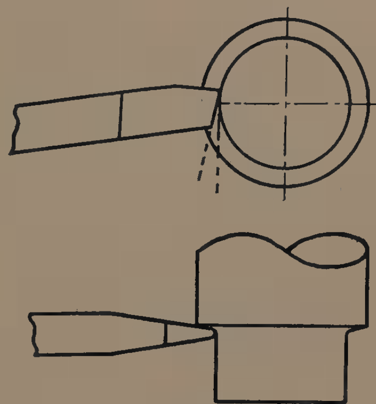
CAST IRON.-Standard 5/8" Tool.

Depth of cut in inches	Feed in inches	Speed in Feet per min for Tool to last 1½ hours before regrinding. Soft Cast iron.	Medium Cast iron.	Hard Cast iron.
3/32"	1/32"	160	80	46·6
	1/16"	110	55	32·2
	1/8"	75·4	37·7	22
1/8"	1/32"	148	74	43·3
	1/16"	104	51·8	32
	1/8"	69·6	34·8	20·3
3/16"	1/64"	183	91·6	68
	1/32"	135	67·5	39·4
	1/16"	94	47	27·4
	1/8"	64·3	32·2	18·8
1/4"	1/64"	171	85·7	50·1
	1/32"	126	63·2	36·9
	1/16"	87·8	43·9	25·6
	3/32"	70·4	35·2	20·6
3/8"	1/64"	156	77·8	45·4
	1/32"	116	57·8	33·8
	1/16"	79·7	39·9	23·3

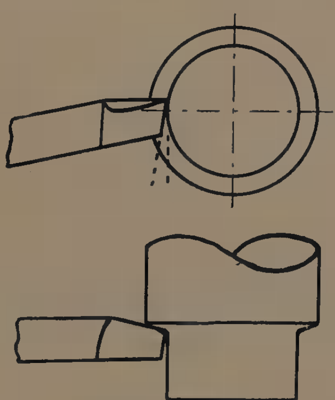
MATERIAL.	HEAVY CUT. Speed F.P.M.	HEAVY CUT. Feed inches	FINISHING CUT. Speed F.P.M.	FINISHING CUT. Feed inches
STEEL - MACHINE.	70	1/32 +	140	1/64 +
STEEL - TOOL	60	1/32 +	120	1/64 +
STEEL - COLD ROLLED.	80	1/32 +	160	1/64 +
STEEL - CAST.	50	1/32 +	80	1/64 +
GRAY IRON-CAST.	60	1/32 +	80	1/64 +
BRASS - SOFT.	160	1/32 +	200	1/64 +
COPPER - SOFT.	160	1/32 +	200	1/64 +
ALUMINUM.	200	1/32 +	200	1/64 +



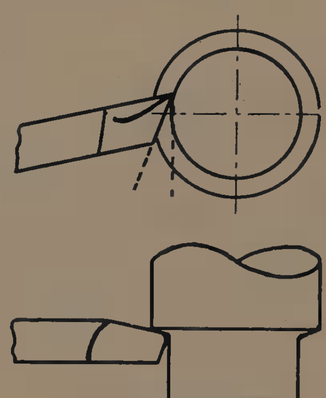
CAST IRON.



BRASS



HARD STEEL



SOFT STEEL.

MATERIAL.	Front clearance	Side clearance	Front rake.	Side rake	Cutting angle	Side cutting angles	working values.
CAST IRON.	10°	10°	0°	15°	80°	65°	10°
BRASS.	6°	10°	−1°	0°	85°	80°	16°
HARD STEEL	5°	5°	10°	25°	75°	60°	5
SOFT STEEL	15°	10°	10°	35°	65	45°	8

TOOL GRINDING for MATERIALS.

DRILLING SPEEDS.							
DIA. of DRILL in INCHES	IRON. STEEL 30 ft per min	CAST IRON 35 ft per min	BRASS 60 ft. per min	DIA. of DRILL in INCHES	IRON STEEL 30 ft per min	CAST IRON 35 ft. per min	BRASS 60 ft per min
	Revolutions per min.				Revolutions per min.		
1/16"	1830	2140	3665.	1 1/2"	75	90	155
1/8"	915	1070	1835	1 9/16"	75	85	145
3/16"	610	715	1220	1 5/8"	70	80	140
1/4"	460	535	915.	1 11/16"	70	80	135
5/16"	365	430	735	1 3/4"	65	75	130
3/8"	305	355	610	1 13/16"	65	75	125
7/16"	260	305	525	1 7/8"	60	70	120
1/2"	230	265	460	1 15/16"	60	70	120
9/16"	205	240	405	2"	55	65	115
5/8"	185	215	365	2 1/16"	55	65	110
11/16"	165	195	335	2 1/8"	55	65	110
3/4"	155	180	305	2 3/16"	50	60	105
13/16"	140	165	280	2 1/4"	50	60	100
7/8"	130	155	260.	2 5/16"	50	60	100
15/16"	120	145	245	2 3/8"	50	55	95
1"	115	135	230	2 7/16"	45	55	95
1 1/16	110	125	215	2 1/2"	45	55	90
1 1/8"	100	120	205	2 9/16"	45	50	90
1 3/16"	95	115	195	2 5/8"	45	50	85
1 1/4"	90	105	185	2 3/4"	40	50	85
1 5/16"	85	100	175	2 7/8"	40	45	80
1 3/8"	85	95	165	3"	40	45	75
1 7/16"	80	95	160.				

LUBRICANTS for CUTTING TOOLS.

OPERATIONS.	METALS.						
	CAST IRON.	MACHINE STEEL or WROUGHT IRON	CARBON or HIGH SPEED STEEL.	COPPER	BRASS or BRONZE.	ALUMINUM.	LEAD or BABBITT
Turning Boring	Dry	Dry, oil or Soda water	Dry or Oil	Milk	Dry	Kerosene or turpentine	Dry
Cutting off Grooving	Dry	Oil or Soda water	Oil or Soda water	Milk	Dry	Kerosene or turpentine	Dry
Screw cutting	Dry	Oil	Oil	Milk	Dry	Kerosene or turpentine	Dry
Tapping	Oil	Oil	Oil	Milk		Kerosene or turpentine	Dry
Threading with dies	Dry	Oil	Oil	Milk	Dry	Kerosene or turpentine	Oil
Drilling	Dry	Oil or Soda water	Oil or Soda water	Milk	Dry	Kerosene or turpentine	Oil
Counter-sinking	Dry	Oil or Soda water	Oil or Soda water	Milk	Dry	Kerosene or turpentine	Oil
Reaming	Dry	Oil.	Oil	Milk	Dry	Kerosene or turpentine	Dry
Counter-boring	Dry	Oil or Soda water	Oil or Soda water	Milk	Dry	Kerosene or turpentine	Oil
Chucking	Dry	Oil or Soda water	Oil or Soda water	Milk	Dry	Kerosene or turpentine.	Dry
Milling	Dry	Oil, soap mixture or Soda water	Oil soap mixture or Soda water	Milk	Dry	Kerosene or turpentine	Dry
Planing	Dry	Dry, oil or Soda water	Dry or Oil	Milk	Dry	Kerosene or turpentine	Dry
Nurling	Oil	Oil	Oil	Milk	Oil	Kerosene or turpentine	Dry
Filing	Dry	Dry or Oil	Dry or Oil	Dry or Milk	Dry	Kerosene or turpentine	Oil
Polishing with Emery cloth	Oil	Oil	Oil	Oil	Oil	Oil.	Oil
TERMS	Oil	LARD OIL	NEVER USE MINERAL OILS		SODA WATER	SAL SODA DISSOLVED IN WATER	

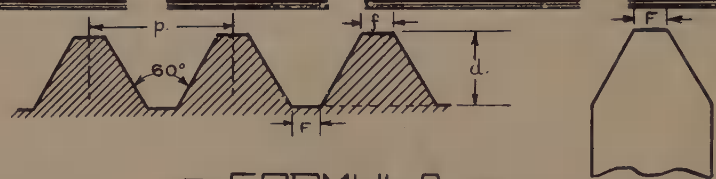
NOTE. When tapping or using die on rolled (not cast brass) use lard oil to prevent clogging

GRINDING WHEEL - GRADE SELECTION TABLE.-		
CLASS of WORK.	GRAIN SIZE	GRADE of HARDNESS (NORTON)
LARGE CAST IRON and STEEL CASTINGS.	12 to 20	Q to U.
SMALL " " " " "	20 .. 30	P .. R.
LARGE MALLEABLE IRON CASTINGS.	14 .. 20	O .. U.
SMALL " " "	20 .. 30	P .. U.
CHILLED IRON CASTINGS	20 .. 30	P .. U.
WROUGHT IRON	12 .. 30	P .. U.
BRASS and BRONZE CASTINGS.	20 .. 36	N .. Q.
ROUGH WORK IN GENERAL	16 .. 30	P .. R.
GENERAL MACHINE SHOP USE.	24 .. 46	O .. P.
LATHE and PLANER TOOLS.	24 .. 46	L .. P.
SMALL TOOLS	36 .. 100	N .. P.
WOOD-WORKING TOOLS	36 .. 60	J .. N.
TWIST DRILLS (HAND GRINDING.)	36 .. 60	M .. N.
" " (SPECIAL MACHINES).	46 .. 60	K .. M.
REAMERS, TAPS, MILLING CUTTERS (HAND GRINDING).	46 .. 100	M .. P.
" " (SPECIAL MACHINES).	46 .. 80	J .. M.
EDGING and JOINTING AGRICULTURAL IMPLEMENTS.	16 .. 30	P .. R.
GRINDING PLOW POINTS.	16 .. 30	P .. R.
SURFACING PLOW BODIES	16 .. 24	P .. R.
STOVE MOUNTING.	20 .. 36	P .. Q.
FINISHING EDGES of STOVES.	30 .. 46	P .. Q
DROP FORGINGS	20 .. 30	P .. R
GUMMING and SHARPENING SAWS	36 .. 60	M .. N.
PLANING MILL and PAPER CUTTING KNIVES.	30 .. 46	J .. K.
CAR WHEEL GRINDING.	20 .. 30	L .. P.

DECIMAL EQUIVALENTS.

64ths	32nds	16ths	8ths	Decimals.	64ths	32nds	16ths	8ths	Decimals.
1/64"				.015625.	33/64"				.515625.
	1/32"			.03125 .		17/32"			.53125.
3/64"				.046875.	35/64"				.546875.
		1/16"		.0625.			9/16"		.5625.
5/64"				.078125.	37/64"				.578125.
	3/32"			.09375.		19/32"			.59375.
7/64"				.109375.	39/64"				.609375.
			1/8"	.125.				5/8"	.625.
9/64"				.140625.	41/64"				.640625.
	5/32"			.15625.		21/32"			.65625.
11/64"				.171875.	43/64"				.671875.
		3/16"		.1875.			11/16"		.6875.
13/64"				.203125.	45/64"				.703125.
	7/32"			.21875.		23/32"			.71875.
15/64"				.234375.	47/64"				.734375.
			1/4"	.250.				3/4"	.750.
17/64"				.265625.	49/64"				.765625.
	9/32"			.28125.		25/32"			.78125.
19/64"				.296875.	51/64"				.796875.
		5/16"		.3125.			13/16"		.8125.
21/64"				.328125.	53/64"				.828125.
	11/32"			.34375.		27/32"			.84375.
23/64"				.359375.	55/64"				.859375.
			3/8"	.375.				7/8"	.875.
25/64"				.390625.	57/64"				.890625.
	13/32"			.40625.		29/32"			.90625.
27/64"				.421875.	59/64"				.921875.
		7/16"		.4375.			15/16"		.9375.
29/64"				.453125.	61/64"				.953125.
	15/32"			.46875.		31/32"			.96875.
31/64"				.484375.	63/64"				.984375.
			1/2"	.500.				1"	1.000000.

UNITED STATES STANDARD THREAD.



FORMULA

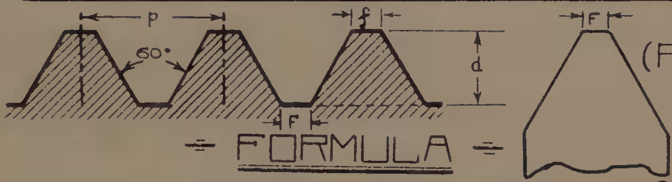
$p = \text{pitch} = \dfrac{1}{\text{No of threads per inch}}$ $d = \text{depth} = \text{pitch} \times .6495$ or $\dfrac{.6495}{n}$

n = No. of threads per inch $f = \text{flat} = \dfrac{\text{pitch}}{8}$

TABLE OF PROPORTIONS

Frac Size	Decimal Equiv. Outside	Threads per Inch	Basic Pitch Diam.	Root Diam	(d) Depth of Thread $\frac{.6495}{n}$	Nearest Commerical Drill Size to produce 75% depth of thread	
						Inch Decimals	Comm Desig'tn
$\frac{1}{4}$	.2500	20	.2175	.1850	.0325	.201	No 7 $\frac{13}{64}$ in
$\frac{5}{16}$	.3125	18	.2764	.2403	.0361	.257	F $\frac{1}{4}$ in
$\frac{3}{8}$	.3750	16	.3344	.2938	.0406	.316	O. $\frac{5}{16}$ in
$\frac{7}{16}$	.4375	14	.3911	.3447	.0464	.368	U. $\frac{23}{64}$ in
$\frac{1}{2}$	.5000	13	.4501	.4001	.0499	.422	$\frac{27}{64}$ in
$\frac{9}{16}$	.5625	12	.5084	.4542	.0541	.422	$\frac{27}{64}$ in
$\frac{5}{8}$	.6250	11	.5660	.5069	.0591	.484	$\frac{31}{64}$ in
$\frac{11}{16}$	.6875	11	.6290	.5694	.0591	.5313	$\frac{17}{32}$ in
$\frac{3}{4}$	.7500	10	.6851	.6201	.0649	.594	$\frac{19}{32}$ in
$\frac{13}{16}$	.8125	10	.7480	.6826	.0649	.656	$\frac{21}{32}$ in
$\frac{7}{8}$	.8750	9	.8029	.7307	.0721	.7188	$\frac{23}{32}$ in
$\frac{15}{16}$	.9375	9	.8650	.7932	.0721	.7656	$\frac{49}{64}$ in
1	1.0000	8	.9188	.8376	.0812	.828	$\frac{53}{64}$ in
$1\frac{1}{8}$	1.1250	7	1.0322	.9394	.0928	.875	$\frac{7}{8}$ in
$1\frac{1}{4}$	1.2500	7	1.1572	1.0644	.0928	.9875	$\frac{15}{16}$ in
$1\frac{3}{8}$	1.3750	6	1.2668	1.1585	.1082	.984	$\frac{63}{64}$ in
$1\frac{1}{2}$	1.5000	6	1.3918	1.2885	.1082	1.0625	$1\frac{1}{16}$ in
$1\frac{5}{8}$	1.6250	$5\frac{1}{2}$	1.5070	1.3888	.1181	1.109	$1\frac{7}{64}$ in.
$1\frac{3}{4}$	1.7500	5	1.6201	1.4902	.1299	1.1875	$1\frac{3}{16}$ in
$1\frac{7}{8}$	1.8750	5	1.7451	1.6152	.1299	1.218	$1\frac{7}{32}$ in
2	2.0000	$4\frac{1}{2}$	1.8557	1.7113	.1444	1.~~3456~~ 781	$1\cancel{\frac{11}{32}}$ in $\frac{25}{32}$

S. A. E. STANDARD THREAD.



(Formerly)
(A.L.A.M.)
(U.S.)
(Form)

FORMULA

p = pitch = $\frac{1}{\text{No of threads per inch}}$
n = No of threads per inch.

d = depth = pitch × .6495 or $\frac{.6495}{n}$
f = flat = $\frac{\text{pitch}}{8}$

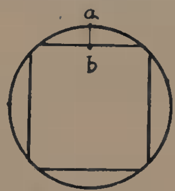
TABLE OF PROPORTIONS

Frac. Size	Decml. Equiv. Outside Diam.	Thds. per Inch	Basic Pitch Diam.	Root Diam.	(d) Depth of Thread $\frac{.6495}{n}$	Nearest Commercial Drill Size to produce 75% depth of Thread	
						Inch Decmls.	Comm. Desig'tn.
$\frac{1}{4}$	.250	28	.227	.204	.0231	.219	№ 2
$\frac{5}{16}$	.3125	24	.285	.258	.0270	.272	I
$\frac{3}{8}$	.375	24	.348	.321	.0270	.332	Q
$\frac{7}{16}$	.4375	20	.405	.373	.0325	.390	$\frac{25}{64}$ in
$\frac{1}{2}$	.500	20	.468	.435	.0325	.453	$\frac{29}{64}$ in
$\frac{9}{16}$	.5625	18	.526	.490	.0361	.515	$\frac{33}{64}$ in
$\frac{5}{8}$	.625	18	.589	.553	.0361	.578	$\frac{37}{64}$ in
$\frac{11}{16}$	.6875	16	.647	.606	.0406	.625	$\frac{5}{8}$ in
$\frac{3}{4}$	.750	16	.709	.669	.0406	.6875	$\frac{11}{16}$ in
$\frac{7}{8}$	.8750	14	.829	.782	.0464	.8125	$\frac{13}{16}$ in
$\frac{7}{8}$	.875	18	.839	.803	.0361	.828	$\frac{53}{64}$ in.
1	1.000	14	.954	.907	.0464	.9375	$\frac{15}{16}$ in.
$1\frac{1}{8}$	1.125	12	1.017	1.017	.0541	1.0496	$1\frac{3}{64}$ in
$1\frac{1}{4}$	1.125	12	1.196	1.142	.0541	1.1719	$1\frac{11}{64}$ in.
$1\frac{3}{8}$	1.375	12	1.321	1.267	.0541	1.2969	$1\frac{19}{64}$ in.
$1\frac{1}{2}$	1.500	12	1.446	1.392	.0541	1.4219	$1\frac{27}{64}$ in.

<u>Note</u> - A common nut, drilled out so that it only contains 50% of a full depth thread will break the bolt before it will strip. A 75% depth of thread yields an ample margin of safety (2 to 1) and is economical in tapping. A full depth of thread in a common nut is about 5% stronger than a 75% thread; yet it requires three times the power to tap.

SHOP MATHEMATICS. SQUARE AND CIRCLE.

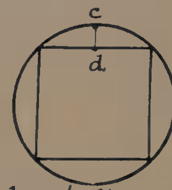
① Square with round corners



$a.b = \frac{1}{8}$ dia. of ⊙

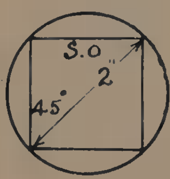
Approximate method.

② Square with sharp corners



$c\,d = \frac{1}{7}$ dia. of ⊙

③



GIVEN Dia. of Stock.

FIND Size of square

S.O = HYP × SINE

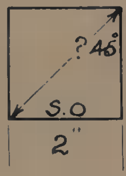
S.O = 2" × SINE of 45°

S.O = 2" × ·7071

S.O = 1·4142

RULE :— Size of square = DIA × ·7071

④



GIVEN SIDE of SQUARE

FIND Dia. of Round Stock.

$$HYP = \frac{S.O.}{SINE.}$$

$$HYP = \frac{2}{\cdot 7071}$$

HYP = 2·82"

RULE :— Dia. of Round stock = $\dfrac{\text{Size of Square}}{\cdot 7071}$

J.

—CUTTING SPEEDS for —MILLING—

	F.P.M.
SOFT GRAY IRON.	70
CAST IRON.	50-60
CAST STEEL.	40
WROUGHT IRON.	45
MALLEABLE IRON.	40-45
MACHINE STEEL.	70-75
CHROME NICKEL STEEL.	45
ANNEALED TOOL STEEL.	30-35
UNANNEALED TOOL STEEL.	20-25
SOFT BRASS.	125
HARD BRASS and COPPER.	90-100
BRONZE	80.
ALUMINUM.	400-600

J.

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